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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CXVII.—No. 3035.] *LONDON: FRIDAY, FEBRUARY 29, 1924.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 3½d.

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See Advertisement page 37.
PATENT WATER-TUBE BOILERS. AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

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THOMAS HUNT & SONS,
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TRANSPORTER CO., LTD.,
CONTRACTING ENGINEERS.
DESIGNERS and BUILDERS
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all Classes of HANDLING MACHINERY.
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RAILWAY AND TRAMWAY ROLLING STOCK.
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MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 129, Trongate, Glasgow. Od 3547
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Patent
See's Hydro-Pneumatic Ash Ejector
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Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 817
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HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 75.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS } ROW'S PATENTS.
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SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS, WATER SOFTENING and FILTERING. 5723

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Tubes AND Fittings AND Steel Plates.
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See Advertisement, page 27. 1872

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Two	26 Kw.	105 Volts.	"Howden-B.E.H.
Two	52 ,,	,, ,,	"Brotherhood - Laurence Scott."
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One	375 ,,	250 ,,	"Allen-Westinghouse."
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One	500 ,,	230 ,,	"Howden-B.T.H."
One	500 ,,	220 ,,	"Bellis-B.T.H."
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One	600 ,,	500 ,,	"Bellis-Mather & Platt."
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Alternating Current, 3-Phase, 50 Periods.

One	400 Kw.	500/550 Volts.	"Howden-G.E.C."
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Two	1000 ,,	,, ,,	"Metropolitan-Vickers."
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One	3000 ,,	6600 ,,	"B.T.H."

All above are modern, and condensing plant is available in nearly all cases.
We can also offer several Suction Gas and Diesel Sets, Babcock Boilers up to 30,000 lbs. per hour, and a very large number of motors, generators, Motor-generators, rotary converters, etc.
Enquiries Invited.
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Works: BURNT MILL, near HARLOW, ESSEX.
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Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
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THE REGENT SHEET METAL MACHINE TOOL CO., LTD., REGENT WORKS, WAKEFIELD. 2015

Metallography with the Super-microscope. Paper read by Dr. Rogers, November 13th, before the Sheffield Metallurgical Society. See page 84.—F. DAVIDSON & CO., 29, Great Portland St., London, W.1. 2009

YARROW & CO. (1922), LTD., GLASGOW.
LAND AND MARINE
YARROW BOILERS. 1553

John Bellamy Limited,
MILLWALL, LONDON, E.
GENERAL CONSTRUCTIONAL ENGINEERS. 1216
Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 56, Feb. 22. 9402

Wanted, Water Softening PLANT for use in conjunction with 30 by 8 Lancashire Boiler. Full particulars and prices.—Address, C 997, Offices of ENGINEERING.

Diesel Engines, 300, 530, 800 and 1,200 B.HP., M.A.N., with or without dynamos; condition as new. About one-third market price; seen London. All spares for above sizes in stock.
HICK DIESEL OIL ENGINES, LTD., 70, Queen Victoria Street, E.C. 4.

Cement.—Maxted & Knott, LTD., Consulting Cement Engineers, ADVISE GENERALLY on proposed Cement Schemes FOR ENGLAND AND ABROAD. ADVICE ONLY. Highest References. Established 1890.
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LIMITED,
STATIONARY, STEAM AND MARINE ENGINEERS.
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54 & 55, FETTER LANE, LONDON, E.C.4.
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See our Illustrated Advertisement, Feb. 8.

Petter Oil Engines.
For Paraffin and Crude Oil
Sizes 1½ B.HP. and upwards.
Petters Limited, Yeovil.
Sizes 25 to 500 B.HP.
Vickers-Petters, Ltd., Ipswich
See advertisement alternate weeks. 9635

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
1676
See half-page Advertisement, page 65, Feb. 15.

The Manchester Steam Users' Association.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

Chief Engineer: C. E. STROMEYER, M.I.C.E.

Founded 1854 by Sir WILLIAM FAIRBAIRN.

Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 2005

PATENTS AND DESIGNS ACTS, 1907 & 1919.

Notice is Hereby Given that

GILL PROPELLER COMPANY LIMITED, a Company registered under the Laws of Great Britain, of Blackfriars Street, King's Lynn, Norfolk, seeks leave to amend the Specification of Letters Patent No. 142713 granted to JAMES HERBERT WAINWRIGHT GILL for "Improvements in and relating to screw propellers and similar appliances."

Particulars of the proposed amendment were set forth in the Illustrated Official Journal (Patents), issued on the 20th February, 1924.

Any person, or persons, may give notice of Opposition to the Amendment by leaving Patents Form No. 19 at the Patent Office, 25, Southampton Buildings, London, W.C.2., within one calendar month from the date of the said Journal.

W. TEMPLE FRANKS, Comptroller-General. D 21

The Greek Legation begs to

Notify all whom it may concern that the INTERNATIONAL COMPETITION, fixed for the 1st March, with regard to the construction, upkeep and exploitation of the public works for the water supply of the towns of Athens and Piræus, has been POSTPONED, and will take place at the Greek Ministry of Communications, Director of Public Works, in Athens, at Noon, on June 1st, 1924.

Full particulars of the proclamation and terms of the competition in question for these works can be obtained, and plans consulted by all those interested, at the GREEK LEGATION, 51, Upper Brook Street London, W.1, between the hours of Twelve and One p.m., and 3.30 to Five p.m. D 83

Correspondence Courses for

Inst.Civil Engrs., Inst.Mech.E., London Univ. (Matric., Inter., B.Sc.), and All ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.E.S.I., F.R.S.A., etc., Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 5/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1993

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1879

TENDERS.

TO IRON FENCING MANUFACTURERS.

The DIRECTORS of the WREXHAM and EAST DENBIGHSHIRE WATER CO. are prepared to receive

Offers for the Supply of 500

Yards or thereabouts of UNCLIMBABLE IRON or STEEL FENCING, 6 ft. high.

Prices and full particulars of the Fencing offered and time required for delivery to be sent to the undersigned not later than 8th March, 1924.

Lowest Tender not necessarily accepted.

FREDERICK STORR, Engineer.

Waterworks Offices, 21, Egerton St., Wrexham. 14th February, 1924. D 18

MIDLAND GREAT WESTERN RAILWAY OF IRELAND COMPANY.

STEEL RAILS AND FISHPLATES.

The Directors of the above-named Company are prepared to receive

Tenders for the Supply of

3500 TONS of STEEL RAILS and corresponding FISHPLATES.

Specification, giving all particulars, can be had on application to the undersigned.

Tenders, sealed and endorsed "Tender for Rails," to be forwarded, addressed to the Chairman, Midland Great Western Railway, Broadstone Terminus, Dublin, so as to reach him not later than Monday, 17th March, 1924.

The Directors do not bind themselves to accept the lowest or any Tender.

PERCY A. HAY, Secretary.

Broadstone Terminus, Dublin. 25th February, 1924. D 36

METROPOLITAN WATER BOARD.

SUPPLY OF SEMI-POSITIVE AND INFERENTIAL TYPE WATER METERS.

The Metropolitan Water Board invite

Tenders for the Supply of

¾ in., 1 in. and 1½ in. SEMI-POSITIVE and 4 in. and 6 in. INFERENTIAL (Siemens) Type WATER METERS, delivered to the Board's Works at Rosoman Street, Clerkenwell, E.C.1.

Forms of Tender may be obtained from the Chief Engineer by personal application (Room 155) or upon forwarding a stamped addressed brief envelope.

Tenders must be made on the official form and be addressed to the "Clerk of the Board, Metropolitan Water Board, New River Head, Rosebery Avenue, E.C.1." endorsed "Tender for Water Meters," and must reach the Offices of the Board not later than Eleven a.m., Friday, 7th March, 1924.

The Board do not bind themselves to accept the lowest or any Tender.

G. F. STRINGER, Clerk of the Board.

Offices of the Board, New River Head, 173, Rosebery Avenue, E.C.1. 27th February, 1924. D 68

THE COMMISSIONERS OF HIS MAJESTY'S WORKS, etc., are prepared to receive

Tenders Before Eleven

a.m., on Thursday, 13th March, 1924, for the SUPPLY of WIRE LIFT ROPES.

Forms of Tender, etc., may be obtained on application to the CONTROLLER OF SUPPLIES, H.M. Office of Works, etc., King Charles Street, Westminster, London, S.W.1. D 62

THE GREAT INDIAN PENINSULA RAILWAY COMPANY, 48, COPTHALL AVENUE, LONDON, E.C.2, invite

Tenders for :—

1.	Mild Steel Bars, Sections, &c.	Fee 10s.
2.	Fencing Materials	,, 5s.
3.	Crank Axles (Machined) for Loco. Engines	,, 10s.
4.	Spare Parts of Locomotive Engines	,, 7s. 6d.
5.	Tyre Retaining Rings ...	,, 5s.
6.	Axle-Boxes for Carriages and Wagons	,, 7s. 6d.
7.	Bolts, Nuts and Rivets, &c.	,, 10s.
8.	Steel Tyres for Loco. Engines and Tenders	,, 10s.
9.	Steel Tyres for Carriages and Wagons	,, 10s.
10.	Laminated Springs	,, 10s.
11.	Gibs and Cotters	,, 5s.
12.	Cast Iron Chairs	,, 7s. 6d.

Tenders are due by Eleven a.m., on 11th March, 1924. Tender Forms obtainable at above address. Fees not returnable. D 72

LONDON AND NORTH EASTERN RAILWAY.

The Directors are prepared to receive

Tenders for the Renewal of the

FLOOR of BRIDGE No. 18, carrying New Bridge Street, Newcastle, over the Newcastle and Berwick Railway at Newcastle-upon-Tyne. The Contract comprises the Supply and Erection of Rolled Steel Beams (800 tons) embedded in concrete, Concrete Road Bed, &c., but not the making of the road surfaces, tramways, drains, &c., which will be carried out by the Newcastle City Engineer. The Contractor is also to remove and purchase the existing W.I. decking (400 tons).

Drawings and Specifications may be seen, and Detailed Quantities and Form of Tender obtained, on personal application at the Branch Office of the Chief Engineer, North Eastern Area, at Forth Banks, Newcastle-upon-Tyne, on and after Thursday, February 28th. Tenders, marked "Tender for Renewal of Floor of Bridge No. 18, Newcastle and Berwick Railway," must be received by the Joint Secretaries, London & North Eastern Railway, Marylebone Station, London, N.W.1, by Nine a.m., Thursday, March 13th.

The Directors do not bind themselves to accept the lowest or any Tender.

JAMES McLAREN, G. F. THURSTON, Joint Secretaries.

Secretary's Office, L.N.E.Rly., Marylebone Station. 25th February, 1924. D 47

COUNTY BOROUGH OF MIDDLESBROUGH.

DOCKS, etc., SCHEME.

The Corporation invite

Tenders for the Construction

of DOCKS, WHARVES, LANDING PLACE, etc., at the site of the Ferry, Middlesbrough.

Copies of Conditions, Specification, and Form of Tender will be supplied on application to the undersigned on payment of a deposit of Five Pounds which will be returned on receipt of a *bona fide* Tender. The plans may be inspected at the Office of Mr. A. C. MITCHELL, M.Inst.C.E., Royal Exchange, Middlesbrough, where arrangements may also be made for loan of prints.

Sealed Tenders, on the Forms and in the envelopes supplied, are to be delivered to the undersigned on or before first post on Monday, the 24th day of March next, and endorsed "Tender for Docks Scheme."

The Council do not bind themselves to accept the lowest or any Tender.

The Scheme will be carried out as work for the relief of unemployment, and the Unemployment Grants Committee's conditions of grant will have to be complied with, which are fully set out in the General Conditions.

PRESTON KITCHEN, Town Clerk.

Municipal Buildings, Middlesbrough. 25th February, 1924. D 46

STATE ELECTRICITY COMMISSION OF VICTORIA.

Melbourne, VICTORIA, AUSTRALIA.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY, etc., of the following for the Morwell Power Scheme.

Copies of Tender Form and Specification will be available upon application to :—

AGENT-GENERAL FOR VICTORIA, Melbourne Place, Strand, London, W.C.2.

SPECIFICATION No. 24/7.

100,000 VOLT TESTING TRANSFORMER.

CHARGE :—10/- for the first two copies of Tender Form, Conditions of Contract and Specification complete. This charge will be returned on receipt of a *bona fide* Tender. A third copy and any further copies will be supplied for the sum of 5/- each. This charge is not returnable.

PRELIMINARY DEPOSIT :—A Preliminary Deposit of £5 is to be lodged with Tender.

The Specifications may be inspected at the above-mentioned office.

The Commission does not bind itself to accept the lowest or any Tender.

Tenders close at the Commission's office, Melbourne, on the 10th March, 1924, and prices should be cabled (cable address, "Electrocom, Melbourne") to the Commission on or before that date, and Tenders on the prescribed form, properly endorsed and addressed, must be forwarded by the following mail to :—

H. LIDDELOW, Secretary, State Electricity Commission of Victoria, Melbourne, Victoria, Australia. C 943

The Director-General,

India Store Department, Branch No. 16, Belvedere Road, Lambeth, S.E.1, REQUIRES :—

1. SCREW COUPLINGS complete, high tensile steel.
2. TUBES, Mild Steel, Galvanized, for steam.
3. MACHINE for Boring Locomotive Cylinders, with electric motor for driving.
4. TUBE FITTINGS, Malleable Iron, Galvanized.

Tenders due on the 11th March, 1924, for No. 1, and on the 21st March, 1924, for Nos. 2 to 4.

Tender Forms obtainable from above. D 59

Sale By Tender.—The

Liquidator of the Variable Pumps and Motors Limited (in Voluntary Liquidation) is prepared to receive TENDERS for the PURCHASE of the whole of the FOREIGN PATENTS relating to improvements in Pumps and other similar apparatus. The Countries covered by these Patents are Australia, Austria, Argentine, Belgium, Canada, Czecho-Slovakia, France, Germany, Hungary, Holland, Italy, Japan, New Zealand, Poland, Spain, Switzerland, United States of America.

Forms of Tender may be obtained from Mr. M. LANCASTER, F.C.A., the Liquidator, at 46, Basinghall Street, London, E.C., to whom all Tenders must be sent not later than Twelve Noon, on the 13th March, 1924. D 66

HOYLAKE AND WEST KIRBY.

THE URBAN DISTRICT COUNCIL OF HOYLAKE AND WEST KIRBY.

HOUSE REFUSE SCREENING PLANT.

The Council are prepared to receive

Tenders for the Supply,

DELIVERY and ERECTION, in building provided, of :—

CONTRACT No. 1. REVOLVING SCREEN or VIBRATORY CASCADE SCREEN.

CONTRACT No. 2. PICKING BELT.

Intending Contractors may quote for either one or both of the above Contracts.

Further particulars and Forms of Tender may be obtained for the above upon written application to the Engineer and Surveyor to the Council, Town Hall, Hoylake.

Sealed Tenders, enclosed in the Special envelope provided and endorsed on the outside "Tender for ....." to be delivered through the post not later than Monday, the 24th day of March, 1924.

The Council do not bind themselves to accept the lowest or any Tender.

R. W. FRASER, Engineer & Surveyor.

Town Hall, Hoylake. 27th February, 1924. D 78

APPOINTMENTS OPEN.

The University of Oxford will

shortly proceed to APPOINT a DIRECTOR of the INSTITUTE for Research in Agricultural Engineering at a salary of £800.

Forms of application may be obtained from the SECRETARY to the Committee for Rural Economy, by whom applications will be received till March 15. C 953

Works Manager.—Midland

Firm of Engineers wish to APPOINT ASSISTANT or UNDERSTUDY to Works Manager. Selected Applicant must be a trained engineer, having served apprenticeship with reputable firm, and possess proofs of thorough knowledge of theory and principles of general engineering. Previous executive experience is desirable. Energy, initiative, inventiveness, enthusiasm for efficiency and broad view in labour problems are essential qualities. Fullest particulars.—Address, C 982, Offices of ENGINEERING.

To Combustion Engineers

and FUEL ECONOMY EXPERTS. Important new Company REQUIRES A RESIDENT BRANCH MANAGER, in each of the following centres, to inspect, advise and report on clients' plants. Sheffield, London, Birmingham, Cardiff, Newcastle-on-Tyne and Liverpool. Commencing salary £300, plus commission and £100 Ord. Shares. Moderate investment required. Full particulars, —Address, D 35, Offices of ENGINEERING.

ASSOCIATED BRITISH MACHINE TOOL MAKERS LTD., 17, Grosvenor Gardens, S.W.1.

Wanted, Manager for

Manchester District Office, with Technical and Commercial experience.

And, for the Birmingham District, REPRESENTATIVE with Expert knowledge of Machine Tools.

Also, for their London Office, an ASSISTANT SECRETARY. Experience in Accountancy essential, and a knowledge of Foreign Trade and language desirable.

Apply by letter, addressed to the CHAIRMAN (which will be treated as strictly confidential), stating age, experience, and salary required. D 29

Assistant Locomotive

SUPERINTENDENT REQUIRED for the NIGERIAN GOVERNMENT RAILWAY for one tour of from 12 to 18 months' service with prospect of permanency. Salary £480 a year for the first three years, then £510, rising by annual increments of £30 to £720, and thence by annual increments of £40 to £920. Outfit allowance of £60 on first appointment. Free quarters and first-class passages and liberal leave on full salary. Candidates, age 25 to 35, should be of good education and preferably possess an approved Engineering Diploma. They should have served an apprenticeship in the Locomotive Workshops of a British Railway and have had experience on the footplate and in fitting, turning and erecting, and in the pattern shop, foundry and drawing office. They MUST have had running experience and should be conversant with running shed procedure and breakdown work.—Apply at once, by letter, stating age and particulars of experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W.1, quoting M/Nig. 12614. D 14

The Royal Air Force

REQUIRES ELECTRICIANS, WIRELESS OPERATORS and POWER STATION TRADESMEN. Age limits: ex-service men 18 to 30; non ex-service 18 to 26. Pay from 24s. 6d. to 38s. 6d. per week on enlistment, and all found. Allowance for wife and children to men 25 and over. —Write, stating age, or call :—INSPECTOR OF RECRUITING, R.A.F., 4, Henrietta Street, Covent Garden, London, W.C.2. C 965

Wanted by Firm of Consulting

Engineers an ASSISTANT ENGINEER, good theoretical and practical knowledge of the steam side of modern power stations essential; age, preferably between 30 and 35.—Applications, stating age, whether married or single, salary required full particulars of experience, and giving two or more references, should be Addressed D 15, Offices of ENGINEERING.

Municipal Engineer

REQUIRED by the GOVERNMENT of the GOLD COAST for Coomassie, for two tours of 12 to 18 months' each. Salary £720-£840 a year and a seniority allowance of £72 a year. Free quarters and passages. Liberal leave on full salary. Candidates, age 30 to 40, should be A.M.I.C.E., or A.M.I.Mun. and Cy.E., or hold equivalent professional qualifications. Must have had previous experience in Town planning and construction and Town road construction, including the design and construction of sewage and main drainage schemes.—Apply at once by letter, stating age and giving brief details of qualifications and experience to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W.1, quoting at top of application M/G.C. 12589. D 15

Assistant Engineers

REQUIRED by the GOVERNMENT OF CEYLON for Railway Construction for two years' service with possible extension. Salary £600 rising to £960 a year by annual increments of £30. Should the selected candidate be less than 30 the commencing salary will be £500 per annum. Free quarters or an allowance in lieu. Free passages provided. Candidates, unmarried, preferably between the ages of 30 and 35, must be experienced engineers who have received good training and experience on a recognised European or American Railway. Must have a thorough knowledge of surveying, levelling, estimating, setting out and supervising all works in connection with the location and construction of a railway. Members or Associate Members of the Institution of Civil Engineers preferred.

Apply at once by letter, stating age and experience to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W.1, quoting M/Ceylon 12610. D 16

PORT OF LONDON AUTHORITY.

Applications are Invited for

the POSITION of CHIEF DRAUGHTSMAN.

Candidates must not exceed 45 years of age and must be capable of organizing and controlling the staff of a large Drawing Office. They must have had a thorough experience in the design of bridges, caissons, gates and dock entrances, and general dock and railway construction and equipment work, and also experience in the preparation of Charts, Reductions and Enlargements.

Applications giving particulars of experience, qualifications, etc., and stating salary required, must be on the prescribed form obtainable from the Staff Manager, Port of London Authority, E.C.3, and be delivered not later than the 31st March, 1924.

Any canvassing of Members of the Authority by or on behalf of an applicant will entail the application being ignored.

F. AYLIFFE, Secretary. C 955

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

An Assistant Engineer is

REQUIRED for the FUEL RESEARCH STATION, East Greenwich, S.E.10. Scale of salary £370 - £20 - £550 plus usual Civil Service bonus. Present commencing pay £430 5 0. Superannuation provision will be made under the Federated Superannuation System for Universities, under which a contribution of approximately 10% of salary is paid by the Department and 5% is paid by the officer.

Candidates should be fully qualified Engineers, with electric power station experience. Research experience is desirable. Preference will be given, other things being equal, to ex-service men.

Applications giving particulars of age, qualifications, Military, etc., with copies of testimonials and/or names of referees, should be made in writing not later than 17th March to the SECRETARY, Department of Scientific and Industrial Research, 16, Old Queen Street, S.W.1. D 40

INDIAN SERVICE OF ENGINEERS.

THE SECRETARY OF STATE FOR INDIA IN COUNCIL will, in 1924,

Appoint 15 Assistant

EXECUTIVE ENGINEERS for this Service, if so many suitable candidates present themselves.

Every Candidate must be a British subject, or a ruler or subject of any State in India in respect of whom the Governor-General of India in Council has made a declaration that he is to be considered eligible.

Candidates must be not less than 21 years of age and not more than 24 years on 1st August, 1924.

They must either (1) have obtained one of certain recognised University degrees or other distinctions in Engineering, or (2) have passed Sections A and B of the Associate Membership Examination of the Institution of Civil Engineers or been exempted by the Institution from such examination, or (3) produce the required evidence that they are otherwise eligible under the Regulations. They must, in addition, have had at least one full year's practical experience of Civil Engineering under a qualified Civil Engineer at the time when they appear before the Selection Committee.

Applications from Candidates must reach the India Office not later than 1st April. Printed forms, together with information regarding the conditions of appointment, may now be obtained from the SECRETARY, Public Works Department, India Office, Whitehall, London, S.W.1. C 941

"ENVELOPING" GEAR TEETH.

THE advantages of the geared turbine as applied to marine propulsion are indisputable, but it cannot be denied that there have been some very disheartening failures. Different opinions are held by different engineers as to the causes responsible. Many have been disposed to blame the workmanship, others the general design or the character of the material used, and it will be remembered that at the Spring meeting of the Institution of Naval

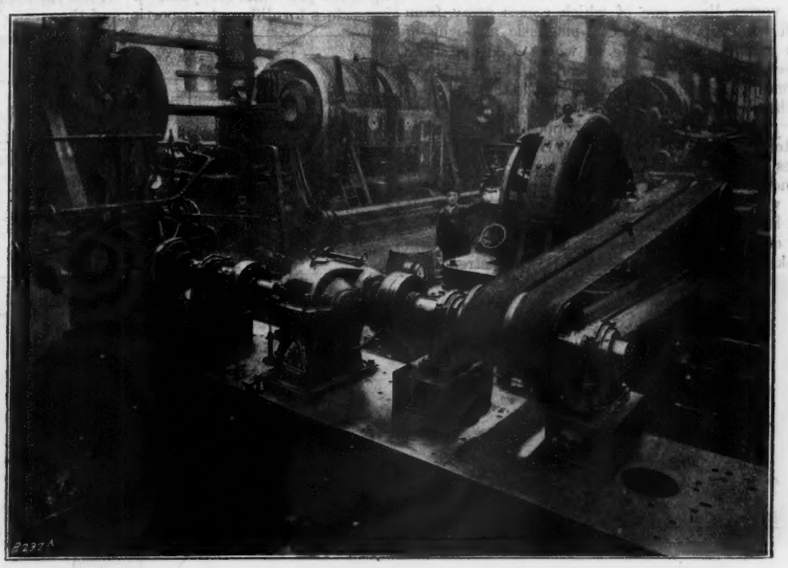


FIG. 1.

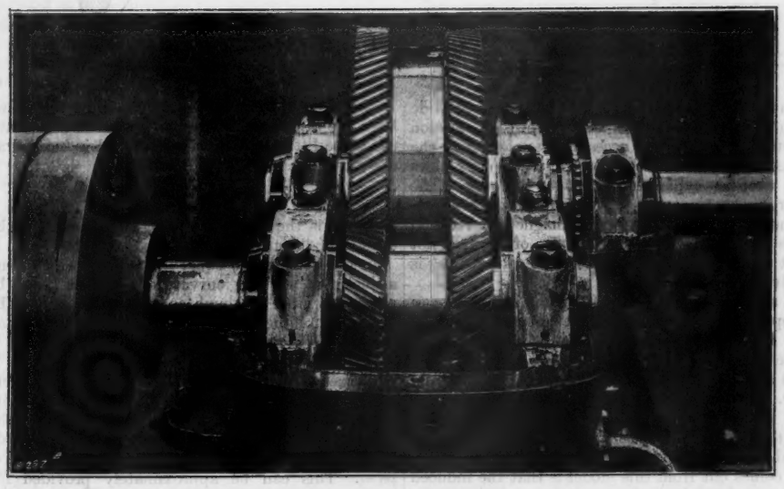


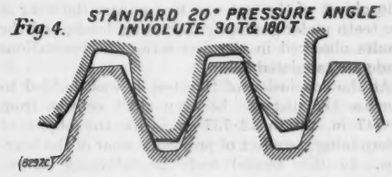
FIG. 2.

Architects last year it was stated that Messrs. C. A. Parsons had come to the conclusion that it was desirable to revert to the use of a softer steel than that which had of recent years come into favour for the pinions. Another interesting proposal has now been brought forward by Messrs. Bostock and Bramley, of Netherton, Huddersfield, who have pointed out that the stress on the material can be greatly reduced by changing the tooth form. We illustrate in Fig. 3 the type of tooth they propose, which, after exhaustive comparative tests, has been definitely adopted by Messrs. Vickers Limited, as the Vickers, Bostock and Bramley "enveloping" gear teeth. The special characteristics of the teeth are, firstly, that engagement takes place only during the arc of recess, and, secondly, that the flanks of the wheel teeth are hollow, thus reducing the relative curvature of the two opposing surfaces. As is well known, the intensity of the pressure due to a given load is greater the greater this relative curvature. When the abutting surfaces are both convex this relative curvature is the sum of the individual curvatures of the two surfaces, but when one is concave and the other convex, the relative curvature is the difference of the two curvatures. The advantage thus gained will be very evident on comparing Fig. 3 with Fig. 4, which represents standard practice with involute teeth. The "enveloping" teeth, it should be added, can be "generated" using the same machine as are employed for cutting involute teeth. The tooth form is intermediate between that of cycloidal teeth and involute teeth. In the new tooth the proportion of slide to roll is notably less than with the involute form, and, as is now well known, the lubrication is twice as efficient when lubricated surfaces roll over each other as when the relative motion is a purely sliding one.

From the above general considerations it will be seen that the form of tooth illustrated might well be expected to give a good result in practice, and this anticipation is very thoroughly borne out by the exhaustive comparative tests made by Messrs. Vickers, Limited. These were made under ideally fair conditions. To this end, it was decided to make a double helical gear pinion to mesh with a double helical gear wheel with a central gap between the two helicals, as shown in Fig. 1, which is reproduced from a photograph. One helical pinion and wheel were cut with the firm's standard involute gear teeth, whilst the other helical pinion and wheel

Fig. 3. ENVELOPING GEARTOOTH 30 T & 180 T.

Fig. 4. STANDARD 20° PRESSURE ANGLE INVOLUTE 30 T & 180 T



were cut with the Vicker's Bostock and Bramley enveloping teeth.

By this arrangement the material of the pinion and wheels were the same for both types of tooth, the mounting, alignment and lubrication were identical, and as the gear wheel was definitely secured against axial travel whilst the pinion shaft, driven through a flexible coupling, was free to move axially, it always adjusted itself automatically, so that the load transmitted was fairly halved between the two types of gear.

TABLE I.—*Comparative Test of "Enveloping" and Involute Gear Teeth.*

H.P.	Hours Run.	K. Value.	Load in lbs. per Inch of Face Width.	Total Hours Run.
0	18·5	0	0	18·5
18	12·0	40	110	30·5
36	19·0	90	220	49·5
55	42·5	130	340	92·0
	A few pits were now distinctly showing on the involute wheel teeth. No pitting on the V., B. and B. teeth.			
74	12·0	180	460	104·0
85	20·0	205	520	124·0
91	3·5	220	560	127·5
100	10·75	240	610	138·25
	A few moderate-sized pits on involute wheel teeth. Numerous small pits showing on involute pinion teeth. No pitting on the V., B. and B. teeth.			
100	5·25	240	610	143·5
120	9·0	290	740	152·5
137	20·75	330	840	173·25
	More pitting showing on involute pinion. No pitting on the V., B. and B. teeth.			
137	11·25	330	840	184·5
	No great increase in pitting on involute pinion. No pitting on the V., B. and B. teeth.			
150	22·0	360	920	206·5
166	4·75	400	1,020	211·25
	Pitting more pronounced on the involute pinion and wheel. No pitting on the V., B. and B. teeth.			
166	21·25	400	1,020	232·5
	The B. and B. wheel now shows slight signs of pitting. No pitting on the teeth of the B. and B. pinion.			
182	17·5	440	1,120	250·0
	Pitting worse on both involute pinion and wheel. Distinct pitting on over half the teeth of the B. & B. wheel. No pitting on the teeth of the V., B. and B. pinion.			
166	20·0	400	1,020	270·0
	Pitting increasing on the involute pinion and wheel. The V., B. and B. wheel unchanged. No pitting on V., B. and B pinion.			

The pinion had in each case, 30 teeth of 0·673 in. circular pitch its pitch diameter was 6·427 in. The wheels had each 89 teeth, the diameter of the pitch circle being 19·067 in. The face width was 2 in. in each case, and the shaft centres were 12·747 in. apart. Both pinions were cut from the one solid forging, of 3·5 per cent. nickel steel, the carbon content of which was about 0·28 per cent. The material was oil hardened after rough machining. The heat-treated material had an ultimate tensile strength of 43·4 tons per sq. in., with an elongation

of 20 per cent. Both the wheels were also cut from one solid forging, the material being carbon steel with an ultimate strength of 34 to 38 tons per sq. in., and a 23 per cent. elongation. Both gears were hobbed on the same machine and by the same operative.

In the tests made the gears were belt-driven, as indicated in Fig. 2. The drive was supplied by an electric motor, and the power transmitted was measured by a Heenan and Froude water-brake dynamometer. The pinion shaft made 800 and the wheel shaft 270 r.p.m.

Messrs. Vickers proportion involute gearing on the basis of a coefficient K, which is defined by the commonly adopted formula

$$K = \frac{\text{load in lb. per in. of face width}}{\sqrt{\text{pitch diameter of pinion.}}}.$$

A common value of K for ordinary marine work is from 180 to 200, and for naval work 220. The object of the test was to compare the wear of the teeth under gradually increasing loads, and the results observed in the first series of observations made are tabulated below.

At the conclusion of this test it was decided to increase the distance between shaft centres from 12·747 in. up to 12·757 in., with the object of determining the effect of prolonged wear of the bearings. In this second test the following figures were recorded :—

H.P.	Hours Run.	K. Value.	Load in lbs. per Inch of Face Width.	Total Hours Run.
85	15·0	205	520	285·0
124	15·0	300	760	300·0

The first test figures show that pitting first appeared on the involute wheel at 55 h.p., but did not develop on the "enveloping" teeth until 166 h.p. was reached. It will also be noted that pitting first showed on the involute pinion at 100 h.p., but the pinion with the enveloping teeth carried a load of 182 h.p. without showing any signs of pitting. It appears, therefore, that under the conditions of the test the latter carried, before pitting, three times the load of the involute wheel.

THE ELEMENTS OF THE LANCHESTER-PRANDTL THEORY OF AEROPLANE LIFT AND DRAG.

*(Concluded from page 171.)**

THERE is another electrical analogy to vortex lines which is even more useful than that described in the preceding article. We can, in fact, always replace a vortex line, characterised by a circulation of Γ per cm., by a wire carrying a current I, the strength of which in C.G.S. units† is given by the relation $I = \frac{\Gamma}{4\pi}$. The magnetic force H produced by this current at any point is numerically equal to the velocity produced at the same point by the corresponding vortex line and both the force and the velocity are directed along the same line.

It is known that any little element Δs of a wire conveying the current I produces a magnetic force at a point P which is given by the expression

$$H = \frac{I}{r^2} \cdot \sin\theta \cdot \Delta s$$

where r denotes the length of the line joining P with the centre of the element in question and θ the angle between this line and Δs. (See Fig. 27.) The direction of the force is perpendicular to the plane containing P and Δs. The velocity produced by the corresponding element of a vortex line is obtained by replacing I in the above expression by $\frac{\Gamma}{4\pi}$ and, as stated, this velocity is directed along the same line as the magnetic force H.

This electro-magnetic analogy is particularly convenient, when the question under discussion is the mutual interference of two wings of a biplane.

The "lift" vortex representing each wing can, from the mathematical standpoint, be replaced by a wire carrying current. If two such wires be fixed in a frame there is no tendency for the frame to move under the mutual interaction of the two magnetic fields and hence we infer that the mutual interaction of the "lift" vortex lines corresponding to the wings of a biplane does not affect the value of the induced drag.

On page 169 *ante* it was pointed out that the trailing vortex lines shed behind a wing wind themselves round the tip vortex lines, so that for many purposes we may consider a monoplane wing as represented by a "lift" vortex line and two trailing vortex lines, one of which comes away from each wing tip. The electro-magnetic analogue of this is represented in Fig. 28 where A A^1 and B B^1 represent two very long horizontal conductors extending indefinitely to right and left. The ends of these on the left are insulated and the ends on the right are connected to opposite poles of a battery. A sliding conductor C D bridges the two wires and represents the lift vortex line corresponding to the wing, whilst D A and C B represent the vortex lines trailing away from each tip. It will be obvious that the magnetic field produced by the current through these trailing conductors will weaken the field on one side of D C and strengthen

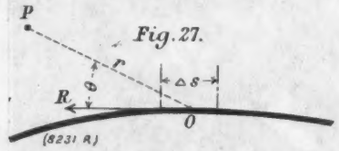


Fig. 27.

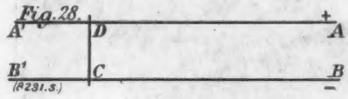
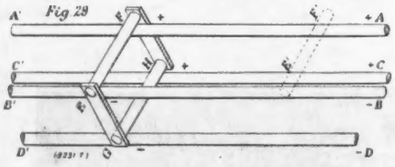


Fig. 28.



it on the other and hence D C will tend to slide along the fixed conductors, and to resist this motion a certain force will be necessary, analogous to the induced drag to which the trailing vortex lines give rise, as explained on page 169 *ante*. The electro-magnetic analogy, though complete so far as the identity of the lines of magnetic force and the stream lines is concerned, is, of course, not exact so far as the direction of the resultant drag is involved.

In similar fashion to the foregoing a biplane can be represented as in Fig. 29 by two parallel conductors, E F and G H mounted on a non-conducting frame and arranged so that F E rests on the parallel wires A^1 A and B^1 B and H G on the wires C^1 C and D^1 D. Here it will be seen that the current through each set of trailing conductors disturbs the field about both the sliders E F and H G, which correspond to the wings. The first important point that comes out from this model is that the induced drag is independent of any stagger of the wings in a fore and aft direction. Thus if E F were displaced to E^1 F^1 the induced magnetic flux round G H will be diminished, as there is now no current through that part of the upper conductors which extends to the left of E^1 F^1. On the other hand an equal length of the lower conductors now extends in front of E^1 F^1 and produces round the latter an additional flux exactly equal to that lost at the lower slider. Hence to calculate the total induced drag, we can consider either slider removed an infinite distance to the left of the other. If, for example, the upper slider is thus removed to infinity, the current in the lower conductors will be too far away to induce any field round this, but on the other hand the drag on the lower slider is increased by the induction due to the current in that part of the upper conductor which lies to the left of G H. Using this model, the induced drag on a biplane can be calculated in the same way as was that on a monoplane, as described in the preceding article. In this way Herr Betz has found that W^1 the total induced drag on a biplane, is given by the expression

$$W^1 = \frac{\sigma A_1 A_2}{\pi q b_1 b_2}$$

where A_1 and A_2 represent the respective lifts of the two wings, b_1 and b_2 the respective spans and q is equal to $\frac{\rho V^2}{2}$ where V is the velocity of flight and ρ the density of the air. The coefficient σ depends upon the gap h and on b_1 and b_2. It has the following values for different proportions of these.

$\frac{2h}{b_1 + b_2}$	Values of σ		
	$\frac{b_2}{b_1} = 1$	$\frac{b_2}{b_1} = 0{\cdot}8$	$\frac{b_2}{b_1} = 0{\cdot}6$
0	1·000	0·800	0·600
0·05	0·780	0·690	0·540
0·1	0·655	0·600	0·485
0·15	0·561	0·523	0·437
0·2	0·485	0·459	0·394
0·3	0·370	0·355	0·315
0·4	0·290	0·282	0·255
0·5	0·230	0·225	0·210

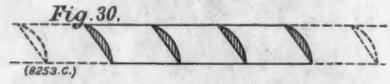


Fig. 30.

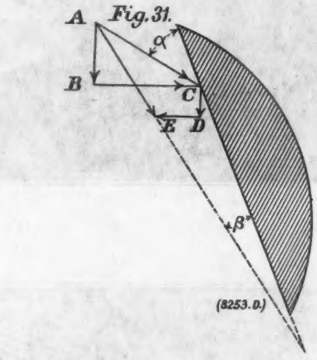


Fig. 31.

The induced drag is a minimum when the planes have the same span and are adjusted so as to have the same lift. In this case the total induced drag is equal to

$$\frac{4 A^2}{\pi \rho V^2 b^2}$$

where A is the lift of one wing, b the span, ρ the density of the air and V the speed of flight.

In order to secure equal lift for the wings some adjustment of the curvature of these may be necessary, since although as already explained the net effect of the interaction of the two-lift vortex lines involves no induced drag, so that the latter is independent of any fore and aft stagger, this is not true as regards lift. Each lift vortex affects the stream lines approaching the other lift vortex. If the upper wing lies in advance of the lower the stream lines approaching it will be bent upwards by the circulation round the lower wing and *vice-versa*. This can be approximately provided for by increasing or diminishing the curvature of the wing by an amount $\frac{1}{R}$ which is given by the relation

$$\frac{1}{R} = \frac{1}{V} \cdot \frac{\partial w_n}{\partial y}$$

where w_n denotes the vertical component of the flow at one wing, due to the lift vortex corresponding to the other, and the axis of y is the axis of flight.

The electro-magnetic analogy described above is of special service in applying the Lanchester-Prandtl theory to the screw propeller. If we take a cylindrical section of such a propeller concentric with its axis and open it out we get a development such as that represented in Fig. 30. From this the analogy to a multiplane is obvious and it should, therefore, be possible to proportion a propeller from the results of wind tunnel experiments on a

* ERRATUM.—Page 171, col. 1. For "Metz and Mark" read "Betz and Munk."

† The C.G.S. unit of current is 10 amperes.

series of blade sections. This suggestion is an old one and has been acted on, but a difficulty arises in determining the true angle of attack. It was shown on page 170, *ante*, that the trailing vortex lines which extend behind an actual wing materially alter the effective angle of attack, and are, moreover, responsible for an induced drag, which is generally of far greater importance than the mere surface friction. Exactly the same kind of thing occurs with a propeller blade.

Consider the blade section indicated in Fig. 31, then if AB represent the speed of the ship, and if BC is equal to the circumferential velocity of the blade section under consideration, then (if we neglect the wake correction) AC will correspond to the velocity of flight in the case of a wing, and α will be the nominal angle of attack. The effect of the trailing vortices is to reduce this angle, since, as will be shown below, they impart both an axial and a tangential motion to the fluid approaching the propeller. Let the former be represented by CD (Fig. 31), and the tangential motion by DE, then the true angle of attack will be the angle β which AE makes with the face of the blade; and it is this

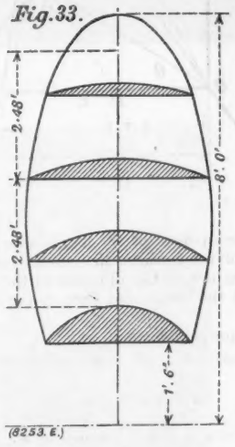
FIG. 32.

angle β at which the blade section should be set in a wind tunnel experiment if the conditions are to correspond to those in which the section has to work when forming part of a propeller blade. Such wind tunnel experiments will show the lift to be expected at different angles of attack, and, also, the angle of no lift which, in the case of a section similar to that represented in Fig. 31 was found by Rateau to be −7 deg. The section experimented on had a versine of 0·086. It should, however, be added that Eiffel's experiments seem to indicate a less extreme value for the angle of no lift.

It will be of interest to make an approximate estimate of the change which the trailing vortex lines induce in the nominal angle of attack and of the induced drag by which the efficiency of the screw is diminished. For simplicity we shall assume that the trailing system of vortices streams away at the tips and the roots of the blades only, and that each section can accordingly be considered as having an infinite aspect ratio. As a matter of experimental fact, the trailing vortices do appear to be strongly concentrated in this way, as is beautifully shown by Fig. 32, which is reproduced from a photograph due to Prof. Flamm. The helices shown represent the cores of vortices which stream away from the tips and roots of the blades. The pitch of the helices streaming away from the roots is, of course, very steep, and hence to the order of the approximation intended, this system may be represented by a single straight vortex line co-linear with the axis of the propeller. The system of vortices corresponding to one blade is then analogous to Ampere's solenoid, which has a return wire passing down its centre. This form of solenoid has the peculiarity that, so far as the external field at a distance is concerned, it can be replaced by a "close wound" helix conveying a current giving the same number of ampere turns per cm. This is not true for points near the helix, however, and the error may be considerable, when the pitch is large. This latter condition is what we get in the case of a propeller. The equations for the flux due to a helical vortex line of steep pitch were given by Major R. A. Low, in a paper read before the Royal Acronautical Society in November, 1922. Unfortunately the integrals found are of a very intractable type, and we shall accordingly assume that the actual tip helices can be replaced by a close wound helix. The assumption is no doubt extreme, and implies that only the vortices which stream from the boss produce any tangential motion of the fluid entering the propeller, so that the losses due to the induced drag will be underestimated. The calculation may, however, provide some idea as to the order of these losses, and may also serve to make clear the general character of the motion of the fluid in the neighbourhood of the screw.

The propeller must be taken as working just inside the helix and is, therefore, situated in the internal field of the system. Reverting to the electro-magnetic analogy, the lines of force which enter here can then be considered as divided into two systems, viz., those produced by the close wound helix, which have both axial and radial components but no tangential component, and secondly the field due to the return wire which has a tangential component only. Corresponding to these systems of lines of force we have, in the case of the propeller, the stream lines induced by the

Fig. 33.



vortex system. The radial component velocity would seem to be largely responsible for the fact that normal propellers in normal working exert no centrifugal effect. Unfortunately this radial velocity can only be expressed in terms of elliptic integrals. The axial component velocity corresponds exactly to the uniform axial magnetic field set up by the current in the solenoid which, if I denote the current in the helix, is equal to $\frac{2\pi I}{p}$ where I is expressed in C.G.S. units, and p is the pitch in cm. of the actual helix formed. If we replace I by $\frac{\Gamma}{4\pi}$ we get the axial velocity produced by the vortex system which trails from the screw.

The tangential velocity due to the "return wire" or axial vortex line is $\frac{\Gamma}{4\pi} \cdot \frac{1}{r}$, where r denotes the radius at which the blade section considered is situated. Did this axial vortex extend indefinitely in both directions the velocity would, of course, be double this, as given on page 2 *ante*.

In Fig. 33 is shown one blade of a four-bladed propeller 16 ft. in diameter and of 16 ft. pitch, which was fitted to a 9-knot cargo boat. At the designed speed the propeller made 64 r.p.m. and absorbed about 760 h.p.

From these data we can calculate an average value for Γ, and thus obtain some approximate idea of the importance of the induced radial and tangential velocities and of the induced drag, which turns out to be very considerable, and is responsible for the waste of a large fraction of the energy supplied.

The torque applied to the propeller was 63,390 ft.-lb., or $8{\cdot}463 \times 10^{11}$ dyne centimetres. It is this torque which balances the "lift" of the propeller blades. At any radius r this lift is equal to $\rho V \Gamma$ dynes per centimetre run (see page 3, *ante*) where ρ denotes the density of the sea-water in grammes per cubic centimetre, which may be taken as 1·026. V is the velocity along the line of flight, which we shall take as the resultant of the forward motion of the ship and of the tangential velocity of the propeller at the radius considered. We shall further assume that the lift is perpendicular to the face of the blade. If the angle which this makes with the axis of the screw be θ, then the torque due to the lift of a section 1 centimetre wide at radius r will be $\rho V \cos\theta\, r\, \Gamma$. Hence, if l denotes the length of the blade, the total torque will be equal to $\rho \Gamma l \times$ the mean value of $r V \cos\theta$ averaged over the whole length of the blade. This mean value is conveniently determined by taking sections of the blade at three Gauss points. Of these one section is at mid-length and the others are situated at a distance of $\frac{l}{2}\sqrt{\frac{3}{5}} = 0{\cdot}3873\, l$ on each side of this mid-section. Since l is 6·4 ft., this distance is 2·48 ft. or 75·6 cm. If, then, we denote the radii corresponding to these sections by r_0, r_1 and r_2 where r_1 refers to the mid-section, then the mean value of $r V \cos\alpha$ is $\frac{1}{18} \cdot (5\, r_0 V_0 \cos\theta_0 + 8\, r_1 V_1 \cos\theta_1 + 5 r_2 V_2 \cos\theta_2)$.

This expression gives accurately the mean height of any curve which can be adequately represented by five ordinates.

In the present case we have the following values:—

Section No.	r Cm.	$\cos\theta$	V Cm. per sec.	$V r \cos\theta$
0	70·7	0·7395	659·9	$0{\cdot}345 \times 10^5$
1	146·3	0·8833	1,084	$1{\cdot}401 \times 10^5$
2	221·9	0·9439	1,558	$3{\cdot}262 \times 10^5$

The mean value is therefore $1{\cdot}624 \times 10^5$. The length of the blade is 6·4 ft., or 195·1 cm. Hence the total torque is $\rho \Gamma l \times 1{\cdot}624 \times 10^5 = 3{\cdot}251 \times 10^7\, \Gamma$. Equating this to the torque at the propeller as already found, we get

$$\Gamma = \frac{8{\cdot}463 \times 10^{11}}{3{\cdot}251 \times 10^7} = 2{\cdot}604 \times 10^4$$

whence

$$\frac{\Gamma}{4\pi} = 2{\cdot}072 \times 10^3.$$

Then, on the assumption that the root vortex system can be adequately represented by an axial vortex line, the tangential velocity imparted to the water approaching the screw is equal to $\frac{\Gamma}{4\pi} \cdot \frac{1}{r}$ cm. per second.

Hence, we find that the induced tangential velocity is 0·96 ft. per second at r_0, 0·46 ft. per second at r_1, and 0·31 ft. per second at r_1.

To determine the axial velocity imparted to the water by the outer system of helices, we shall assume that the pitch of these helices is the same as that of the screw, which is 16 ft., or 487·7 cm. If this helix were a wire carrying a current it would produce an axial magnetic flux equal to $\frac{2\pi I}{p}$. Replacing I by $\frac{\Gamma}{4\pi}$, the axial velocity due to the helical vortex lines is

$$\frac{2\pi\Gamma}{4\pi p} = \frac{2\pi \times 2{\cdot}072 \times 10^3}{487{\cdot}7} = 26{\cdot}68 \text{ cm.}$$

per second, or 0·88 ft. per second.

The induced drag due to the tangential and axial velocities can be calculated. Taking a 1 cm. length at each Gauss point, this drag will be $\rho w \Gamma$ dynes, where w denotes the induced velocity perpendicular to the "line of flight," which, as before, we shall

take as sufficiently well represented by the resultant of the speed of the ship and of the tangential velocity of the Gauss point considered. If we denote by ϕ the angle this makes with the propeller axis, the value of w is $t \cos \phi + s \sin \phi$, where t denotes the induced circumferential velocity at the point considered and s the axial velocity there. We thus get the values given in Table I:—

TABLE I.—Values of the "Induced" Velocities and Drag at the Three-Gauss Points of a Propeller Blade.

Section No.	ϕ	Cos ϕ.	Sin ϕ.	t, cm. per sec.	s, cm. per sec.	w, cm. per sec.	Induced drag dynes per cm. run.	V, cm. per sec.	Energy wasted ergs. per cm. run per sec.
0	45°-40′	0·6989	0·7153	29·28	26·68	39·55	$105 \times 10{\cdot}57$	659·9	$10^8 \times 6{\cdot}968$
1	64°-42′	0·4274	0·9041	14·17	26·68	30·17	$105 \times 8{\cdot}058$	1084·0	$10^8 \times 8{\cdot}734$
2	72°-42′	0·2974	0·9548	9·34	26·68	28·25	$105 \times 7{\cdot}544$	1558·0	$10^8 \times 11{\cdot}75$

This induced drag is along the "line of flight." The velocity of the propeller element along this line is equal to V, which is taken at the values given in the last column but one, and hence the energy wasted per centimetre of blade-length at each of the Gauss points is as tabulated in the last column.

The mean value is found as before, and comes out at $10^8 \times 9{\cdot}080$ ergs. per second per centimetre run. The blade length being 195·1 cm., the total energy wasted in the induced drag is $10^8 \times 9{\cdot}080 \times 195{\cdot}1 = 1{\cdot}772 \times 10^{11}$ ergs. per second, which is equal to 13,070 ft.-lb. per second, or about 20 h.p.

As stated at the outset, the assumptions on which the above analysis is based are somewhat sweeping, and the induced drag is probably materially higher than here found. The induced velocities, of course, alter the effective angle of attack by the amount $\frac{w}{V}$ as explained on page 170, *ante*.

In conclusion, it may be of service to point out that the velocity produced at any point Q by the element Δs of a vortex line is most easily determined by elementary vector geometry. This velocity is given both as to amount and direction by the expression

$$\frac{\Gamma}{4\pi} \cdot \frac{V \rho \delta}{r^3}$$

where $V \rho \delta$* denotes the vector product of ρ and δ, where ρ denotes the vector between Q and Δs, and δ a unit vector along Δs, whilst r denotes the length of the vector ρ expressed in centimetres. The value of r is readily found from the expression

$$-r^2 = -\rho^2 = \ldots$$

To take an example, let B C, Fig. 34, represent part of a ring of wire of radius a having its centre on the axis O Y. Then if Δs be a short element of this ring, we require to find the flux produced at Q by a current I circulating in the wire. Let O P be the vector from O to the mid-point of the element. Take as co-ordinates of reference the three unit vectors i, j and k as shown. Then since vectors are added graphically, we see from the figure that

$$\begin{aligned} \text{O P} &= \text{O A} + y \,.\, j = a \cos\theta \,.\, i - a \,.\, \sin\theta \,.\, k + y \,.\, j \\ &= \text{O Q} + \text{Q P} = \eta a \,.\, i + \text{Q P}. \end{aligned}$$

Hence if we denote the vector Q P by ρ, we get

$$\rho = a(\cos\theta - \eta) \,.\, i - a \sin\theta \,.\, k + y \,.\, j.$$

Let δ denote a unit vector along Δs. Then this vector is perpendicular to the plane containing the vector O A and the vector j.

Now $\cos\theta \,.\, i - \sin\theta \,.\, k$ represents a unit vector along O A. Hence δ is the vector product of this vector and the vector j, or

$$\begin{aligned} \delta &= V \,.\, j(\cos\theta \,.\, i - \sin\theta \,.\, k) \\ &= \cos\theta \,.\, j\, i - \sin\theta \,.\, j\, k. \end{aligned}$$

But by the rule for the multiplication of unit vectors at right angles to each other, we have

$$\begin{aligned} i \,.\, j &= k = -j \,.\, i \\ j \,.\, k &= i = -k \,.\, j \\ k \,.\, i &= j = -i \,.\, k, \end{aligned}$$

and also

$$i^2 = j^2 = k^2 = -1,$$

which is not a vector at all, but a mere number.

* The V here, as in what follows, has nothing to do with velocity, but $V \rho \delta$ is Hamilton's notation for the vector part of the product of ρ and δ. Similarly he denotes the purely numerical or scalar part of such a product by $S \rho \delta$.

Applying the above rules to the value found for δ we get

$$\delta = -\cos\theta \,.\, k - \sin\theta \,.$$

Then the flux at Q is equal to

$$\frac{I}{r^3} \,.\, \frac{V \rho \delta}{r^3} \Delta x$$

$$= \frac{I}{r^3} [a(\cos\theta - \eta)\, i - a \sin\theta \,.\, k + y \,.\, j] \times [-\cos\theta \,.\, k - \sin\theta \,.\, i]$$

$$= \frac{I \Delta x}{r^3} \,.\, [-a(\cos^2\theta - \eta\cos\theta)\, i\, k + a \sin^2\theta \,.\, k \,.\, i - y \cos\theta \,.\, j\, k - y \sin\theta \,.\, j\, i]$$

$$= \frac{I \Delta x}{r^3} [a(\cos^2\theta - \eta\cos\theta)\, j + a \sin^2\theta\, j - y\cos\theta\, i + y \sin\theta \,.\, k]$$

$$= \frac{I \,.\, \Delta x}{r^3} \,.\, [a(1 - \eta\cos\theta)\, j - y\cos\theta\, i + y \sin\theta \,.\, k].$$

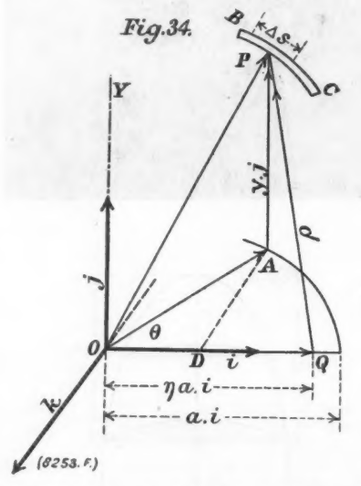


Fig. 34.

The axial component of the flux is thus given by the term involving j, whilst the second term gives the component flux in the direction of the vector i, and the third the component flux in the direction of k.

To determine r we have

$$-r^2 = \rho^2 = a^2(\cos\theta - \eta)^2 \,.\, i^2 + a^2 \sin^2\theta \,.\, k^2 + y^2 \,.\, j^2.$$

And since

$$i^2 = k^2 = j^2 = -1,$$

we get

$$r^2 = a^2(1 + \eta^2 - 2\eta\cos\theta) + y^2.$$

Hence by this elementary vector geometry we obtain in one operation all three components of the flux produced at Q by the element Δx, and the determination of the flux produced by the whole ring, of which Δx forms one element, is thus reduced to a mere matter of integrating the expressions thus found.

33,000-VOLT BULK SUPPLY SCHEME FOR GORSEINON.

An interesting example of the bulk supply of electricity by overhead mains at a high voltage is furnished by the installation recently put into operation at Gorseinon and Pontardulais, in South Wales. The bulk supply is made at 33,000 volts, which has been adopted by the Electricity Commissioners as one of the standard main transmission voltages for this country. There are other transmissions at this voltage in Great Britain, but not very many of them, and the details of the Gorseinon plant are of considerable interest not only on account of the voltage adopted, but because the installation may be taken as a representative example of a class of work which is likely to be undertaken to a very considerable extent in the future.

Gorseinon, which is one of the main centres of the tinplate industry, is situated on the Gower Peninsula and is about six miles from Swansea. For a number of years a supply has been given in the district by the Gorseinon Electric Light Company, Limited, which operates under a Provisional Order granted to them by the Board of Trade in 1910. Up to the putting into operation of the 33,000-volt transmission scheme, with which we are here mainly concerned, the company has supplied direct current at 200 volts from a gas-engine power station at Gorseinon, distribution being by overhead wires. The company has been very successful and the great proportion of the houses in the town are taking a supply. This success, coupled with a growing industrial demand, resulted in a situation which it was not possible for the company to deal with properly by any extension of their original generating

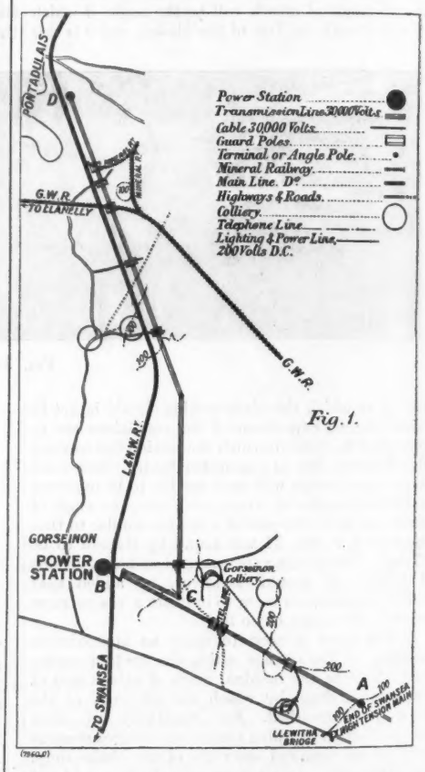


Fig. 1.

system, and some type of complete reorganisation had to be contemplated. In these circumstances the company appointed Messrs. Arthur Ellis and Partners, of Cardiff, as their consulting engineers, and the new scheme has been carried through by this firm, which has been responsible for the scheme itself, the details connected with it and the necessary specifications.

In view of the fact that a bulk supply was ascertained to be available from the Swansea Corporation the company was advised by Messrs. Arthur Ellis to enter into an agreement for the taking of such a supply. This proposal, which is consonant with modern ideas, had the advantage of enabling the company to expend their energies and any monies they had available in the developing of their distribution system, and the cultivation of their own area and the adoption of the scheme is likely ultimately largely to influence the future progress of the district covered by the company's activities. After the scheme had been accepted by the company it was submitted to and approved by the Electricity Commissioners before the necessary work was put in hand. The scheme involved the provision by the Swansea Corporation of a transmission line from one of their existing substations to a point on the boundary between the Corporation area and that

33,000-VOLT BULK SUPPLY SCHEME FOR GORSEINON.

MESSRS. ARTHUR ELLIS AND PARTNERS, ENGINEERS, CARDIFF.

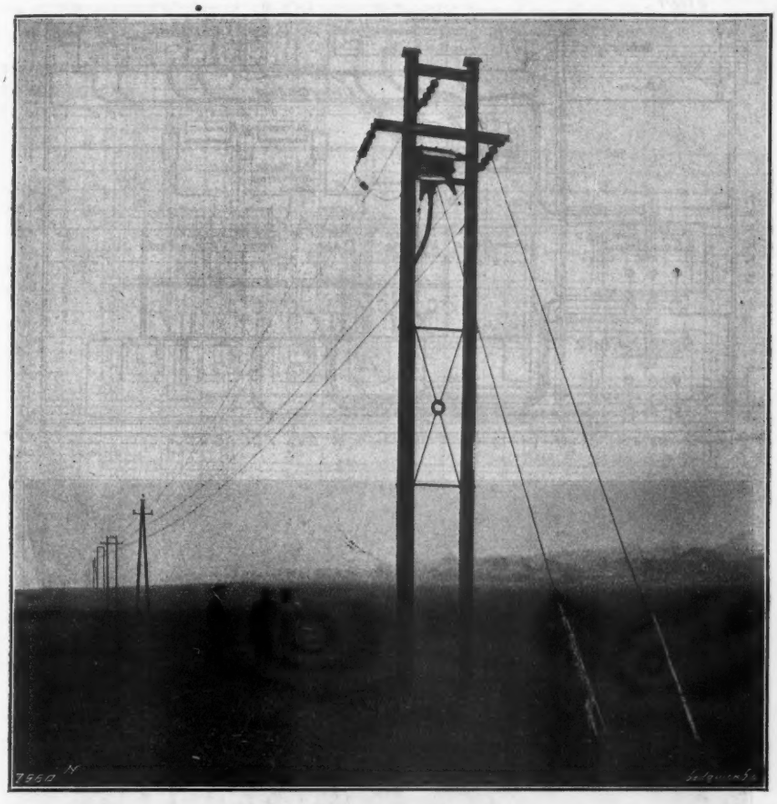


FIG. 2. THE TRANSMISSION LINE.

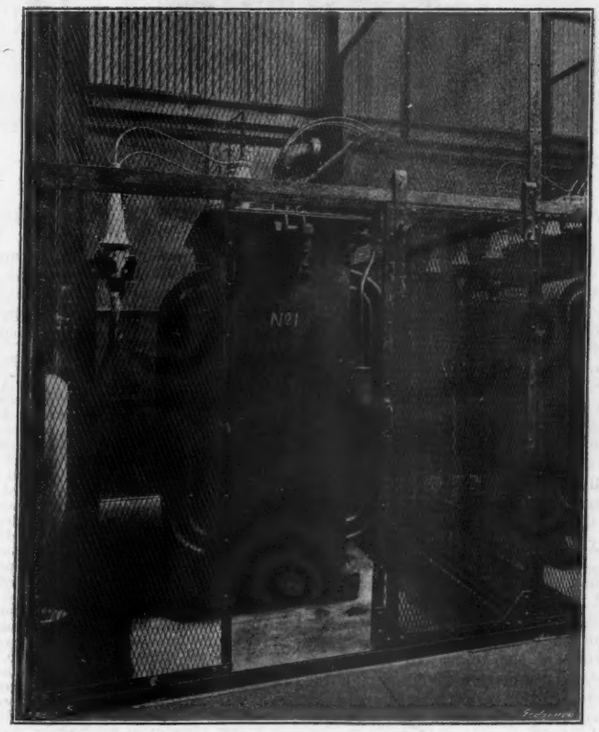


FIG. 3. 625-KW. TRANSFORMER.

served by the Gorseinon Electric Light Company. This point, which is situated at Llewitha Bridge, is indicated at A in the map of the scheme which is given in Fig. 1 on page 260. At Llewitha Bridge, the 33,000-volt lines of the Swansea Corporation and the company are connected together by isolating links, and from this point the lines are carried almost into the centre of Gorseinon, where a new substation has been built. The position is indicated at B in Fig. 1. An outgoing 33,000-volt overhead feeder from this station connects to a generally similar substation at Pontardulais, indicated at D, which also lies in the company's area of supply. The routes of the transmission lines are shown in Fig. 1.

The new substation at Gorseinon is situated in the centre of the town, alongside the old gas-engine station, and the incoming 33,000-volt line from Llewitha Bridge has been stopped short some few hundred yards away, connection through the town proper being made by underground cable. The same arrangement is used in connection with the outgoing feeder to Pontardulais, the two terminal poles carrying respectively the Llewitha Bridge and Pontardulais lines standing on either side of the main Swansea road. One of these terminal poles—that of the Pontardulais line—is shown in Fig. 2. There are in all about 8 miles of this 33,000-volt transmission, for which wooden poles have been used throughout. The transmission lines, together with the short lengths of 33,000-volt connecting cable, were supplied and erected by British Insulated and Helsby Cables, Limited, of Prescot. A plain three-wire line with wires 0·5 sq. in. sectional area is used throughout the overhead transmission. Both of the types of pole which are used are shown in Fig. 2. The standard pole is the A form, but at terminals and where guard wires have to be accommodated the H construction is used. The H poles, which can be seen in the middle distance in Fig. 2, carry guard wires at a point where the line crosses a public track crossing the common over which the line lies.

The supply to the whole of the district is controlled in the first place from the main substation at Gorseinon, while the supply to Pontardulais is locally controlled from the substation in that area. A plan of the Gorseinon substation, showing the arrangement of the apparatus it contains, is given in Fig. 4 on page 262. The 33,000-volt supply which is received at the station is converted to 3,300 volts for distribution to large consumers in the area and is further reduced to 400 and 230 volts for public and private lighting. The whole of the equipment of this station, as well as of the generally similar station at Pontardulais, was supplied by the General Electric Company, Limited, of Witton, Birmingham. The transformers, however, were built by Messrs. Ferranti, Limited, of Hollinwood, who acted as sub-contractors. For the main conversion from 33,000 to 3,300 volts two 625 k.v.a. oil-cooled transformers are installed, one of which is illustrated in Fig. 3. Each transformer is situated in an expanded metal cubicle, and, as will be seen from Fig. 3, space is available for a further unit as demand grows. Provision is also made in connection with the switching gear for such future extension.

The main 33,000-volt switch gear consists of four cubicles, controlling respectively the incoming feeder from Swansea, the outgoing feeder to Pontardulais and the 33,000-volt sides of the two 625 k.v.a. transformers. As before explained the feeders enter and leave the station as underground mains, and the actual arrangement of the connection between these mains and the switch cubicles is well shown in Figs. 4 and 5, this latter figure being a view of the cable trench at the back of the 33,000-volt gear. Connection to the transformers is made with single core cables which terminate in insulators mounted on the side of the transformer compartments as shown in Fig. 3. Bare wire connections are run from these to the transformer terminals.

In addition to the 33,000-volt switch cubicles, the station also contains a seven-panel 3,300-volt board which controls the 3,300-volt sides of the main transformers and also the high-tension sides of two smaller step-down transformers which supply the 400-volt board from which the low-tension supply is distributed. Two further panels control outgoing 3,300-volt feeders and the seventh is a metering panel. As will be seen from Fig. 4 this board is

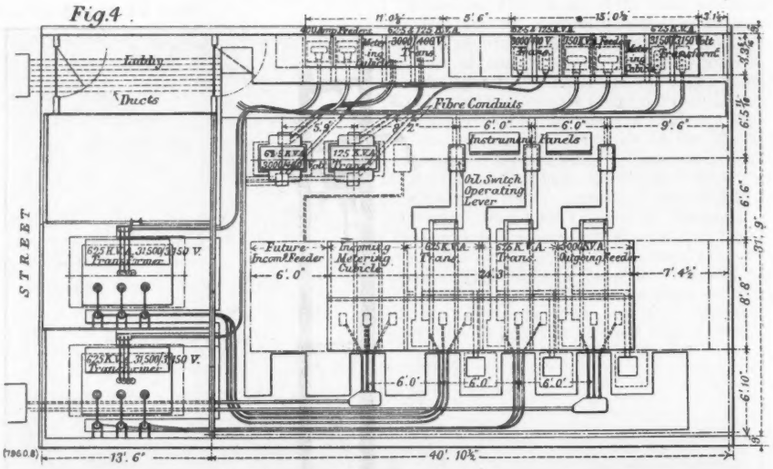
mounted against the station wall and alongside it there is a 400-volt board controlling the low-tension sides of the small transformers and two outgoing feeders. The two 3,300-volt to 400-volt transformers are indicated in Fig. 4. They are respectively of 125 k.v.a. and 62·5 k.v.a., but larger transformers can be installed in the position they occupy as the load grows. There is a further 3,300-volt switch panel which is not indicated in Fig. 4. This controls a 250-kw. rotary converter which has been installed in the old power station which is situated alongside the new sub-station with which we are concerned. This panel is connected up to the bus-bars of the 3,300-volt board by single-core cables. The converter has been installed in order to afford a direct-current supply to the old distribution system which was fed from the old gas engine generating plant which has now been shut down. This system will ultimately be changed over to suit a three-phase supply, but this will involve a considerable re-arrangement of the overhead wiring as well as possible modification of consumers' appliances and will take a considerable time to carry out. The rotary converter was supplied by the General Electric Company.

(To be continued.)

33,000-VOLT BULK SUPPLY SCHEME FOR GORSEINON.

MESSRS. ARTHUR ELLIS AND PARTNERS, ENGINEERS, CARDIFF.

Fig.4.



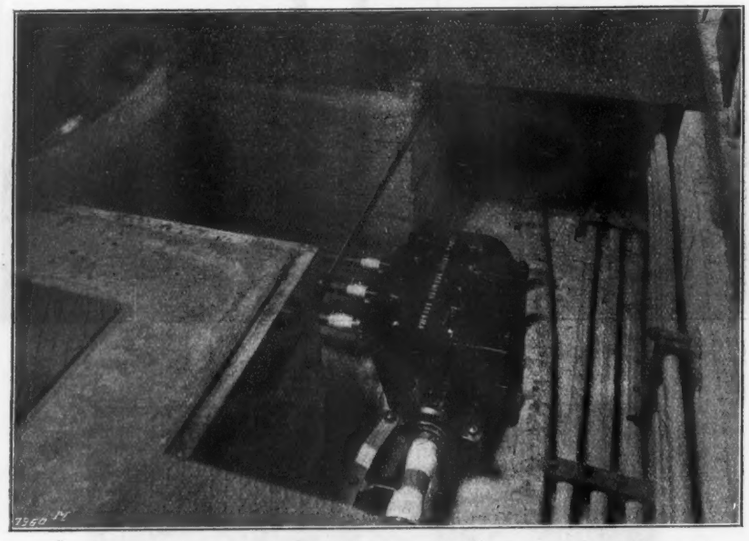


FIG. 5. CABLE DUCTS BEHIND 33-VOLT CUBICLES.

HOME TRADE WITH NEW ZEALAND.

THE import and export returns of New Zealand for the last complete year for which figures are available, that ending on December 31, 1922, show an apparent balance in favour of the Dominion of 7,713,688*l.*, which is a very satisfactory improvement on the figures for the two previous years. The apparent position is not a true index, however, of the extent of the recovery, for accumulated stocks which had been held in New Zealand are now completely cleared. The figures relating to the trade done each month are very informative of the stages in which the improvement has been effected. The monthly returns of imports showed a rapid fall during the first half of the year 1921, averaged about two and a-half million pounds during the following twelve months, then expanded steadily during the second half of 1922, and in the first six months of 1923 the average monthly returns reached three and a-half million pounds, in spite of the generally reduced level of prices. This is further evidence of the prevailing opinion that the stocks of goods held in the Dominion have now been completely liquidated and that buying is now in more reasonable relationship to the immediate demands. For this information, and the figures relating to British trade in New Zealand, we are indebted to a report on The Economic and Commercial Conditions in the Dominion of New Zealand to July, 1923, which Mr. N. Elmslie, His Majesty's Trade Commissioner, presented to the Department of Oversea Trade, and which has been published as one of the regular series of trade reports.

Of her total imports, the Dominion received from the United Kingdom 48·5 per cent. in 1921, 52·25 per cent. in 1922, and 53·05 per cent. in the first half of 1923. The continuous increase of the share of the Homeland in this market is a very happy state of affairs, and it may be added that in the trade in competitive manufactures the position at present is practically what was the condition in the year 1914. The increase in trade obtained by the United States and Australia during the European War has been almost completely lost, but Canada has maintained her position and actually increased her trade during the last six months covered by Mr. Elmslie's report. As the embargo on German trade was only removed in September last, no official figures are as yet available of the extent of the change, if any, over what was experienced during the period when trading licences were necessary. The ships engaged in the New Zealand trade are almost entirely British. New services have been instituted by the Canadian Government Merchant Marine, and regularity of service is being kept up by the discharge and loading of cargo at only one port in New Zealand. The present system of loading at a large number of ports, some of which are little better than open roadsteads, is one of the causes of the high cost of sea carriage. Port charges amount in the aggregate to considerable sums, and it is obviously uneconomical for large overseas steamers to spend lengthy periods in collecting cargo at small ports which could be shipped in a fraction of the time from one or two well-equipped main centres. As there are other transport charges to be set off against the gains due to the concentration of the loading at a single port, and possible deterioration and loss of value of the goods due to additional handling, there seems, at present, to be little hope of the introduction of a proper and effective remedy for these difficulties.

In the metal market, the United Kingdom now has 76 per cent. of the trade, which represents a complete recovery to the pre-war position. There are decreases in the total values, however, amounting to over two million pounds, due to the lower prices obtainable for many classes of material. In most of the sections of this trade the home country holds a great supremacy, but in the case of fencing wire the United States is the predominant participant, while Canada has quite a considerable share. In telephones and related accessories, Belgium supplies two-thirds of the requirements, while the United Kingdom and the United States each have about one-seventh of the trade. In machinery, although the total demand showed a decrease during the last complete year for which returns are available, the United Kingdom obtained an increased share, and now holds 63·6 per cent. of the trade. It is contended that the improvement is mainly due to the more satisfactory footing on wh ch the British traders are put by the Customs Tariff of 1921, which, by a preference, removes many of the disadvantages of trade in competitive manufactures. Great progress is reported in the development of hydro-electric supplies of power in New Zealand, and many new schemes are now in contemplation.

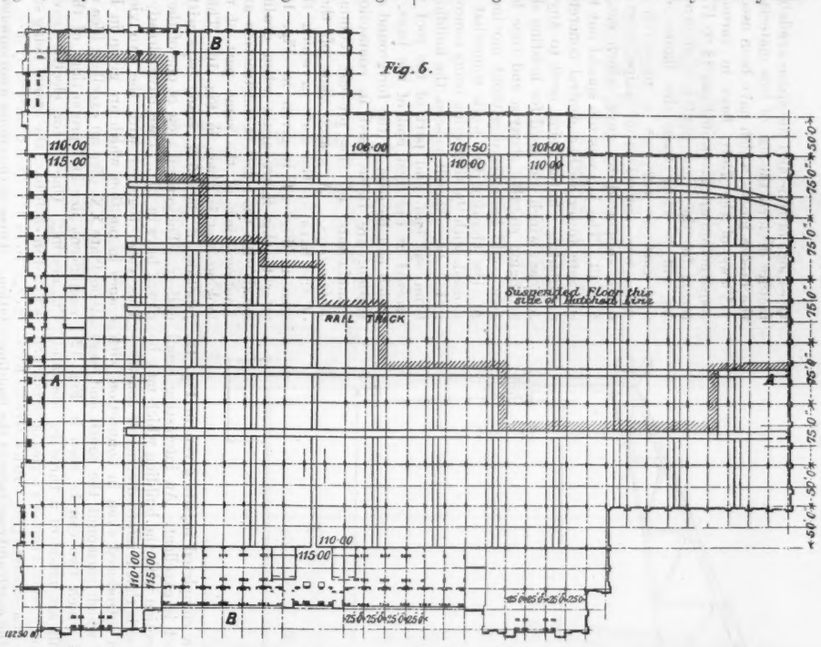
MINERAL PRODUCTS OF HUNAN.—According to the Chinese Government Bureau of Economic Information, Hunan is rich in mineral products. A ton of gold ore sometimes yields more than an ounce of gold. Silver ore is found only with lead. The Suikowshan lead mines are producing some silver. There are copper mines in several places where the metal is found occasionally in a free state. The richest mines are at Mokwo in the Pingkiang district. There are iron mines in the Siang and Tze river valleys. Well-known deposits are also in numerous other districts. The methods used in working these deposits are primitive. There are a number of tin mines in the southern part of the province. The tin mine at Shanghwalin in the Linwu district is a Government-owned mine. Tin ore has also been found at Kianghwa. The best known lead and zinc mines are those at Suikowshan, but lead mines also exist at other places of the province. In recent years a number of manganese mines have been opened up, and all are being worked. That at Yoling in the Siangtan district, worked by the Yu Sheng Company, is reported to yield rich ores. Hunan is well known for its production of antimony. Mercury, also, is found at Houchiping either in a free state or in combination with other minerals, while tungsten ore has been discovered at several places in the Tzehing and the Jucheng districts.

THE BRITISH EMPIRE EXHIBITION BUILDINGS.

(*Continued from page* 228.)

WE may now proceed to a description of the Palace of Engineering, a plan of which is given in Fig. 6, subjoined. This is the largest building in the exhibition and covers probably a larger area than any other ferro-concrete building in the world. Longitudinal and cross-sections of the building are given in Figs. 8 and 9 on page 264, together with a larger scale view of one of the 75 ft. bays in Fig. 10; from these, in conjunction with Fig. 6, it will be seen that it is divided into 11 bays, of which five are 75 ft. wide and are equipped with 25-ton overhead travelling cranes. The remaining bays are each 50 ft. wide. The five 75 ft. bays are served by standard gauge railway tracks. As will be seen from Figs. 6 and 8 there are two 50 ft. cross-bays at the west end of the building. The total overall length is 950 ft. and the greatest overall width is 725 ft. The floor area of the building is over half-a-million square feet. A general idea of the proportions of the building will be given by Fig. 17 on Plate XIX, which is an interior view of one of the 75 ft. bays. As will be seen the general effect of these bays is very fine.

Fig. 6.



As mentioned in our issue of last week, the site on which the building stands had a considerable slope to the north when operations were commenced, and although no attempt was made to level the exhibition site as a whole it was naturally necessary to deal with the actual area which was to be occupied by this Palace of Engineering. As the excavations for this building were commenced only in August, 1922, the question of the amount of levelling which would be justified in view of the time available and also on the score of expense required much consideration. The land was not entirely levelled and part of the floor is carried on brick piers. This can be seen at the left-hand side of Fig. 9, while the actual area carried in this way is outlined by the hatched line in Fig. 6. The bearing of the question of expense is illustrated by the fact that experience and calculation showed that had the floor level been fixed lower than the actual position determined on and shown in Fig. 6, each inch lower than the level was actually taken would have cost 10,000*l.* The level determined upon, and which has been worked to, has allowed of the suspended floor being arranged for without the necessity of any of the brick piers on which it is carried, being more than 4 ft. high.

The Palace of Engineering lies to the east side of the main north and south avenue of the exhibition, and as the levelling carried out on the site of the building was of a local nature, for reasons already explained, the final result has been that the level of the floor is somewhat below that of the main avenue. This condition has been met by arranging a stepped floor at the west end of the building, as can be seen in Fig. 8. The raised floor, or platform, which is known as the restaurant level, as a large restaurant is built on part of it, forms an excellent position for an outlook over the whole building and makes a good point of approach. The main entrances are made at a slight slope and no steps have to be traversed by visitors entering through them.

The area covered by the Palace of Industry, as well as that covered by the Palace of Engineering had to be levelled, the two buildings lying on either side of the main avenue, as shown in Fig. 1, on page 225 of our issue of February 22. Although the actual depth of earth dealt with was not very great, the quantity was considerable owing to the area covered. In all, including excavations for foundations, some 80,000 cubic yards of excavation was carried out in connection with these two buildings. Owing, however, to the very large area concerned it was not considered practicable to utilize any type of digging machinery in connection with the work, and the levelling was carried out by hand labour. No great depth of earth had to be dealt with on any part of the site, and any excavating machinery would have spent most of its time in being shifted from one position to another rather than in getting on with the job. As the land was levelled the foundations for the columns were put in and the floor was laid, as is shown in the general view given in Fig. 7 annexed. The suspended flooring consists of

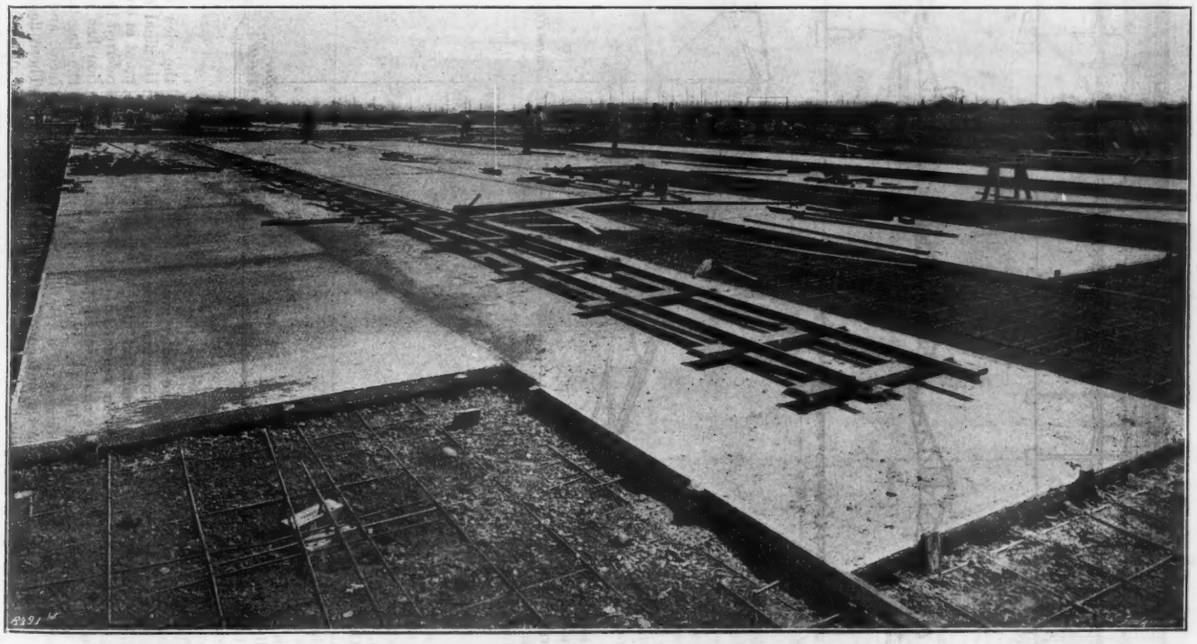
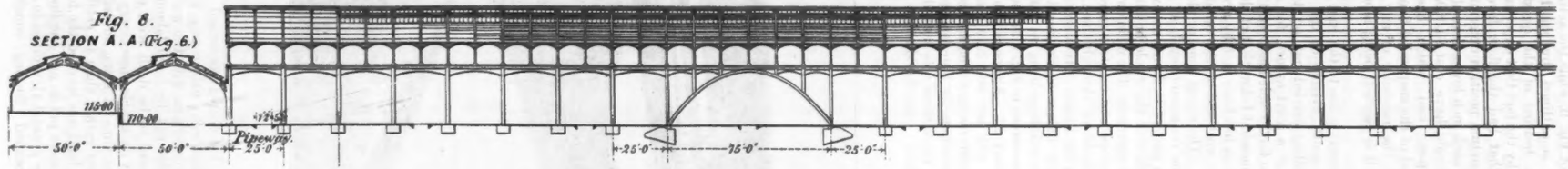
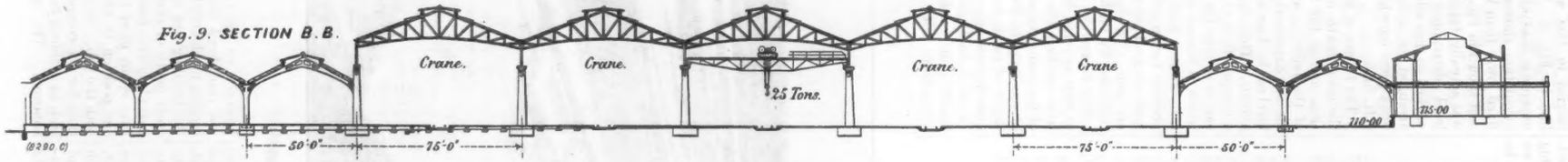


FIG. 7. CONCRETE FLOORING OF PALACE OF ENGINEERING.

THE BRITISH EMPIRE EXHIBITION BUILDINGS; THE PALACE OF ENGINEERING.

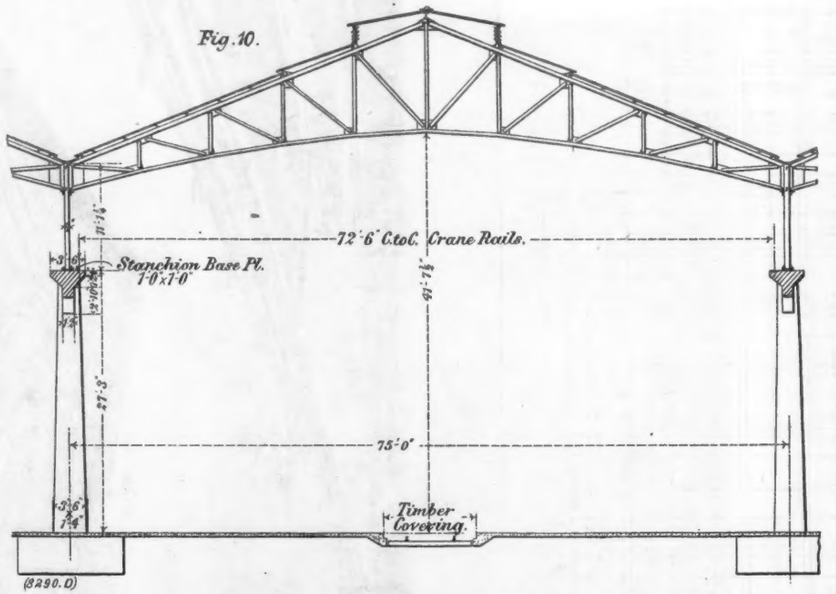




mass concrete slabs carrying brick piers, which in turn carry the 4-in. reinforced concrete slab. The foundations are of a simple nature and had not in general to be taken down to any great depth, although in isolated positions piling was used. The foundation blocks to the columns were in most cases carried down to a depth of about 4 ft. They are in mass concrete, but have splice bars lapping the reinforcement to columns.

Before referring to some of the details of the ferro-concrete and steel structural work, it will perhaps be well to describe the arrangement of the building somewhat more fully than we have yet done. The best general idea of the lay-out is probably given by Fig. 9. This is a cross-section taken north and south parallel to the main avenue of the exhibition. Its position is indicated at BB in Fig. 6. As will be seen there are five main 75 ft. bays with three 50 ft. bays to either side of them. In both types of bay the columns are spaced at 25 ft. centres, as shown in Fig. 8, which is an east and west cross-section, taken on the line AA of Fig. 6. A 75 ft. cross-aisle, over which the crane rails are carried by ferro-concrete arches, has been formed towards the east end of the building, as shown in Fig. 8. These arches, which can be seen in the view of the completed building, given in Fig. 17 on Plate XIX, form an important architectural feature of the interior. Special foundation blocks are provided below the springing of these arches, as shown in Fig. 8. The 75 ft. bays are furnished with railway tracks for the bringing in and removal of the heavy engineering exhibits which will have to be housed. The rail tracks lie below the level of the concrete floor, as shown in Figs. 9 and 10, and the gaps in which they run will be filled in with timber during the time the exhibition is open to the public.

A good general idea of the main structural features of the building will be obtained from the constructional views given in Figs. 11 to 17 on Plates XVII to XIX. Both the 75-ft. and 50-ft. bays are self-supporting erections, and the south and west



façades and the outer walls on the north and east, from a structural point of view, merely act as screens closing in the building. The façade structure is in reinforced concrete, and a view showing the shuttering in position during erection is given in Fig. 11. Structurally this part of the building consists of a reinforced-concrete skeleton filled in on the outer face with breeze blocks. The blocks, which were made on site, were faced with cement during manufacture and before they were removed from the moulds, and, as will be seen from the view of a completed façade given in Fig. 12, the final effect is excellent. An interesting small point in connection with the building which may be referred to here is that reinforced-concrete construction has been introduced even in connection with the flagstaffs which surmount the south and west faces, and of which two can be seen in Fig. 12. These flagstaffs are made of a three to one sand-cement mixture moulded round a series of bars much in the manner of a concrete pile. Brick screens have been used for the north and east faces of the building. Questions of time and the space available for manufacture decided the use of this material in place of the breeze blocks which have been used elsewhere.

Views of the 75-ft. bays in various stages of construction are given in Figs. 13 to 17. The shuttering for the crane gantry is shown in Fig. 13. As will be clear from this figure, each gantry was cast *in situ*, as a monolith. The concrete was poured from skips from a movable tower supported by guys, which can be seen in Fig. 13. The job was too spread out to allow of a concrete tower with a central concrete plant and distributing chutes being used to any advantage. A steam winch was used for hoisting skips, and by arranging suitable sheaves and rope leads a large area could be covered without moving the winch. A view showing the work somewhat further advanced, with the shuttering being removed, is shown in Fig. 14. As will be seen, the building progressed from one end, and part of the roof can be seen erected at the west end of the bays. The forms which can be seen in the foreground of this illustration, are those used in connection with the manufacture of the pre-cast columns for the 50-ft. bays. A nearer view of the west end of the bays in the state in which they can be seen in Fig. 14 is given in Fig. 15. We will refer to this figure again when dealing more in detail with the concrete construction and the roof. Another view of the same part of the building looking east is given in Fig. 16. This shows the junction of the 75 ft. crane bays with the 75 ft. gallery. The general view of one of the nearly completed bays in Fig. 17 we have already referred to. This view, together with the two views showing cranes in position which are given in Figs. 18 and 19 on Plate XX, give an excellent idea of the really magnificent size and proportions of the Palace of Engineering. One 25-ton electric travelling crane is fitted in each bay, the cranes being supplied with energy from the direct-current system of the exhibition. Three of the cranes were supplied by Messrs.

THE PALACE OF ENGINEERING AT THE BRITISH EMPIRE EXHIBITION.

(*For Description, see Page* 263.)

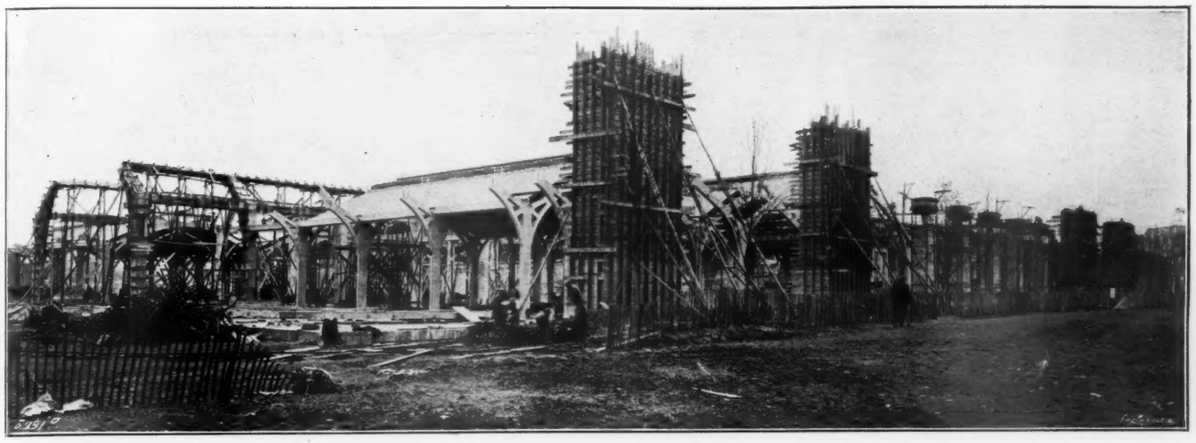


FIG. 11. SHUTTERING FOR FAÇADE.

FIG. 12. COMPLETED FAÇADE.

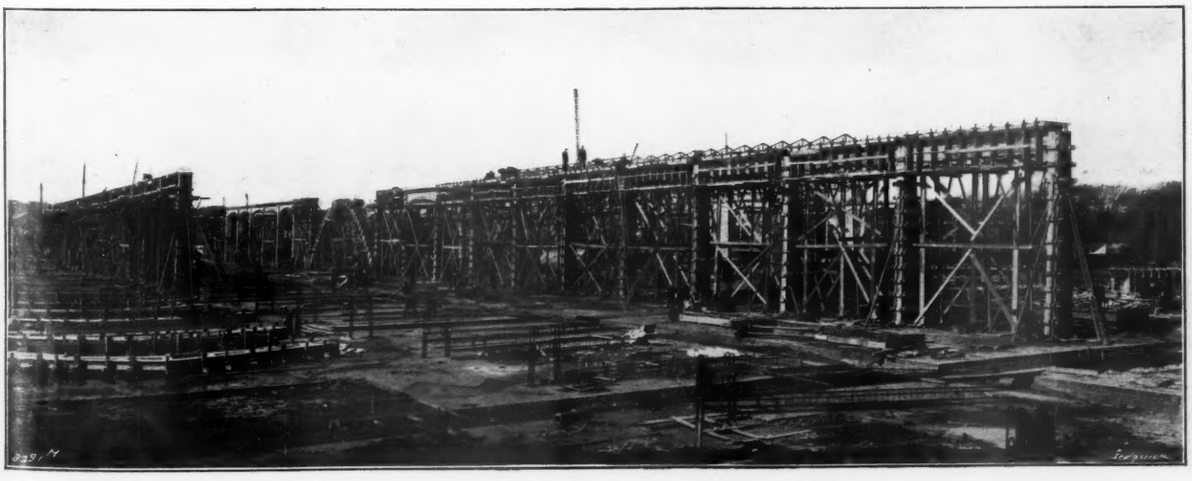


FIG. 13. SHUTTERING FOR CRANE GANTRIES.

(*To face page* 264.)

THE PALACE OF ENGINEERING AT THE BRITISH EMPIRE EXHIBITION.

(*For Description, see Page* 263.)

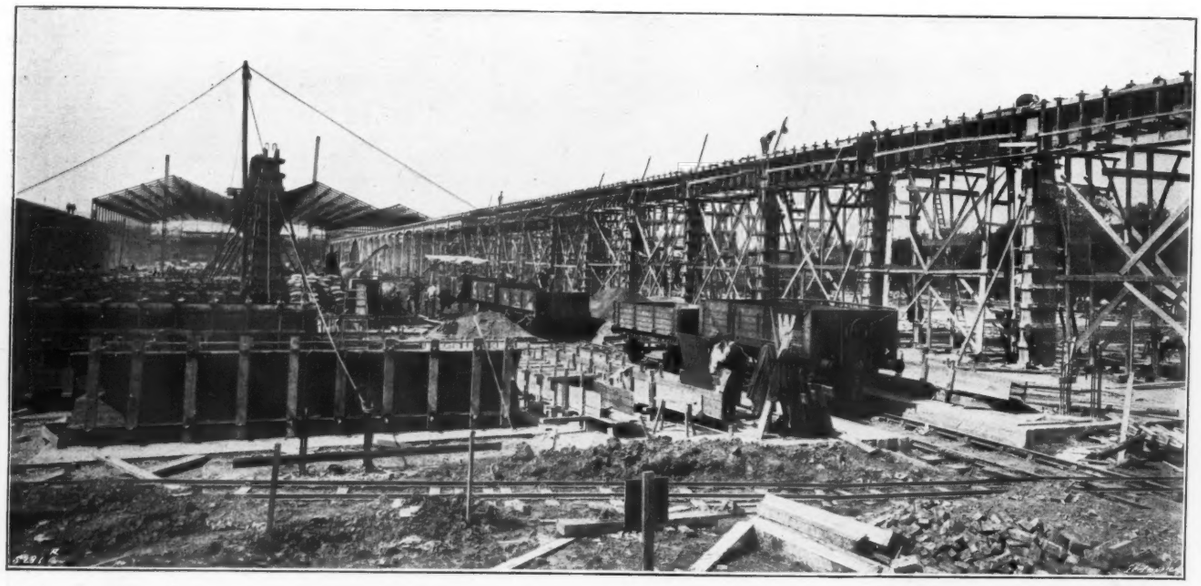


FIG. 14. CRANE GANTRY APPROACHING COMPLETION.

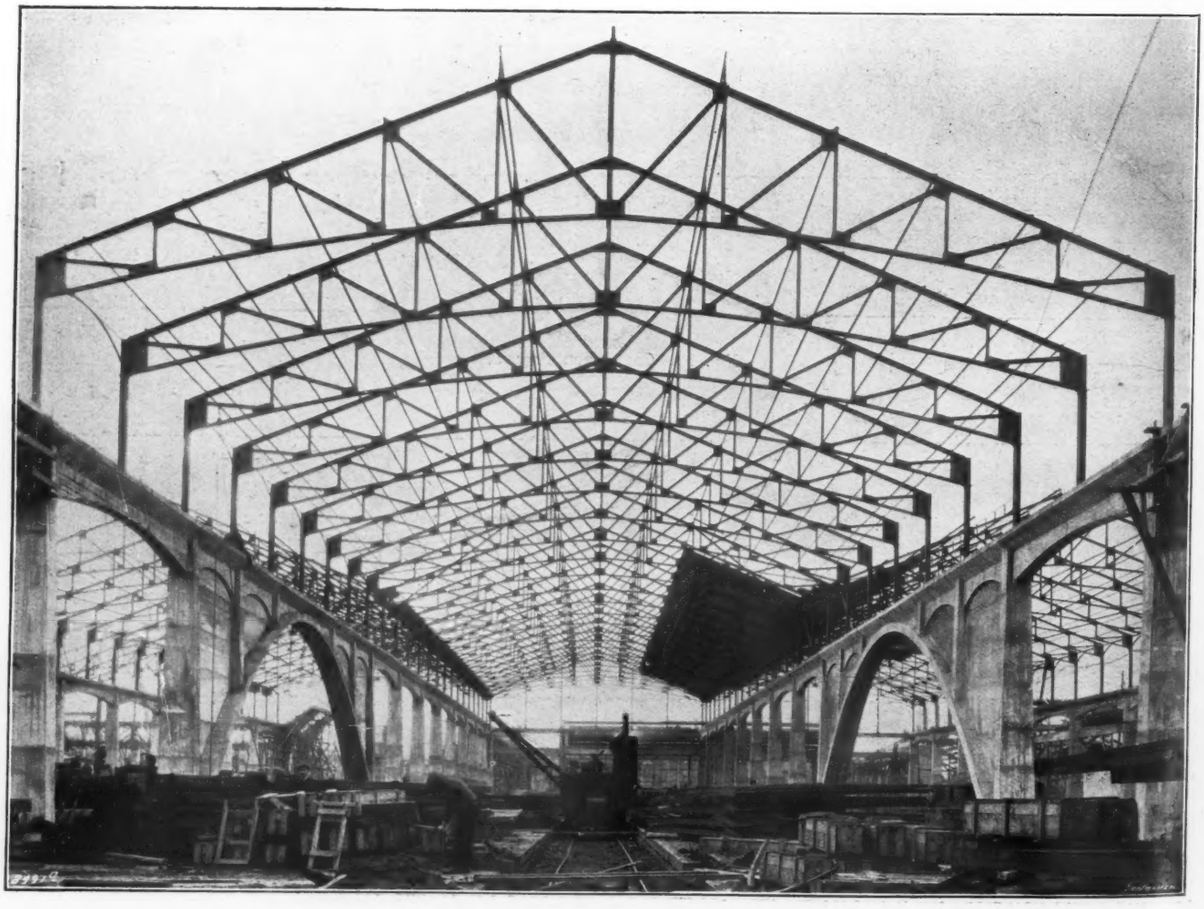


FIG. 15. ROOF PRINCIPALS OF 75-FT. CRANE BAY.

THE PALACE OF ENGINEERING AT THE BRITISH EMPIRE EXHIBITION.

(*For Description, see Page* 263.)

FIG. 16. JUNCTION OF 75-FT. CRANE BAY AND 75-FT. GALLERY DURING ERECTION.

FIG. 17. 75-FT. CRANE BAY NEARLY COMPLETED.

THE PALACE OF ENGINEERING AT THE BRITISH EMPIRE EXHIBITION.

(*For Description, see Page* 263.)

FIG. 18. 25-TON OVERHEAD CRANE ERECTED.

FIG. 19. 25-TON OVERHEAD CRANE DURING TEST.

(*To face page* 265.)

THE BRITISH EMPIRE EXHIBITION BUILDINGS; THE PALACE OF ENGINEERING.

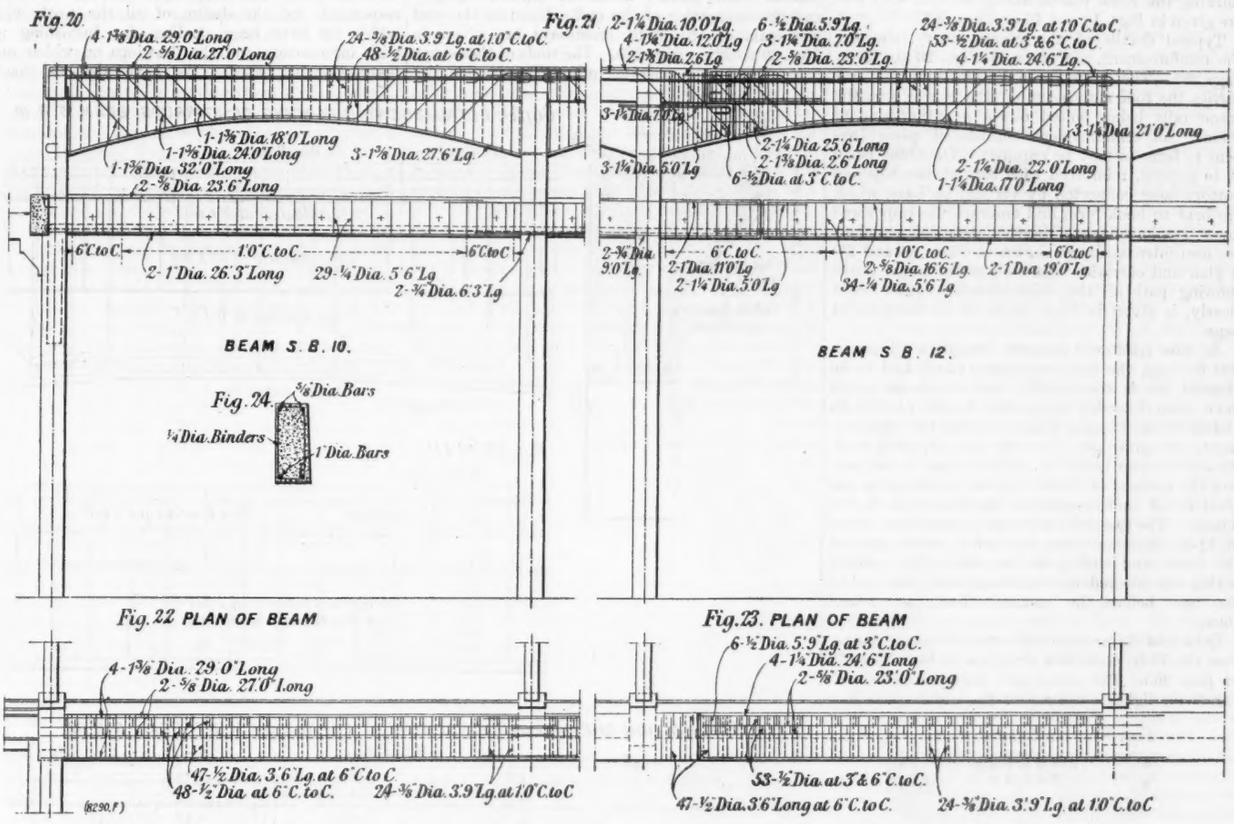
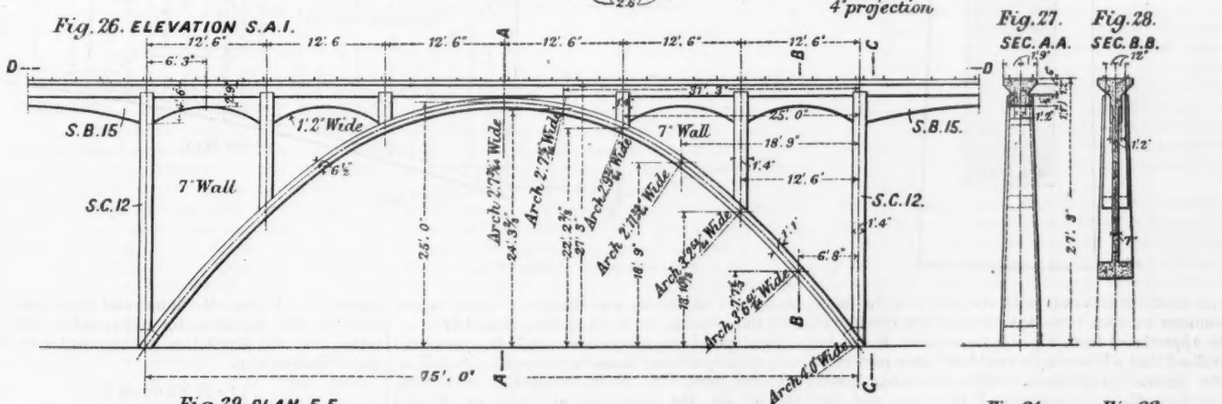
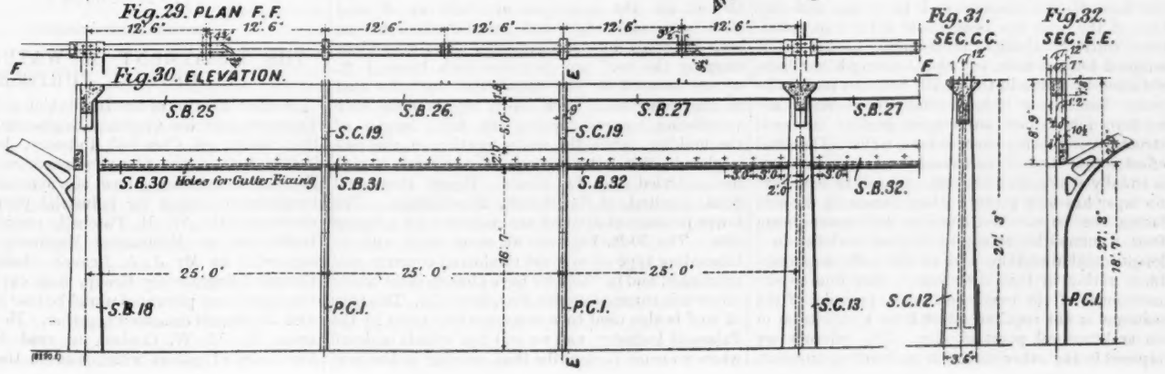


Fig. 20.
4-1⅜ Dia. 29'0" Long
2-⅝ Dia. 27'0" Long
24-⅜ Dia. 3'9" Lg. at 1'0" C. to C.
48-½ Dia. at 6" C. to C.
1-1⅜ Dia. 18'0" Long
1-1⅜ Dia. 24'0" Long
1-1⅜ Dia. 32'0" Long
3-1⅜ Dia. 27'6" Lg.
2-⅝ Dia. 23'6" Long
6" C. to C.
1'0" C. to C.
6" C. to C.
2-1" Dia. 26'3" Long
29-¼ Dia. 5'6" Lg.
2-¾ Dia. 6'3" Lg.
BEAM S. B. 10.
Fig. 21.
2-1¼ Dia. 10'0" Lg.
4-1¼ Dia. 12'0" Lg.
2-1⅛ Dia. 2'6" Lg.
6-½ Dia. 5'9" Lg.
3-1¼ Dia. 7'0" Lg.
2-⅝ Dia. 23'0" Lg.
24-⅜ Dia. 3'9" Lg. at 1'0" C. to C.
53-½ Dia. at 3" & 6" C. to C.
4-1¼ Dia. 24'6" Lg.
3-1⅛ Dia. 7'0" Lg.
3-1¼ Dia. 21'0" Long
2-1¼ Dia. 25'6" Long
2-1⅜ Dia. 2'6" Long
3-1¼ Dia. 5'0" Lg.
6-½ Dia. at 3" C. to C.
2-1¼ Dia. 22'0" Long
1-1¼ Dia. 17'0" Long
2-¾ Dia. 9'0" Lg.
6" C. to C.
10" C. to C.
6" C. to C.
2-1 Dia. 11'0" Lg.
2-1¼ Dia. 5'0" Lg.
2-⅝ Dia. 16'6" Lg.
34-¼ Dia. 5'6" Lg.
2-1 Dia. 19'0" Lg.
BEAM S B. 12.
Fig. 24.
⅝ Dia. Bars
¼ Dia. Binders
1" Dia. Bars

Fig. 22 PLAN OF BEAM
4-1⅜ Dia. 29'0" Long
2-⅝ Dia. 27'0" Long
47-½ Dia. 3'6" Lg. at 6" C. to C.
48-½ Dia. at 6" C. to C.
24-⅜ Dia. 3'9" Lg. at 1'0" C. to C.
(8290. F.)
Fig. 23. PLAN OF BEAM
6-½ Dia. 5'9" Lg. at 3" C. to C.
4-1¼ Dia. 24'6" Long
2-⅝ Dia. 23'0" Long
53-½ Dia. at 3" & 6" C. to C.
47-½ Dia. 3'6" Long at 6" C. to C.
24-⅜ Dia. 3'9" Lg. at 1'0" C. to C.





Sir William Arrol and Co., Limited, and two by Messrs. Babcock and Wilcox, Limited. Views showing the Arrol cranes during erection and test are given in Figs. 18 and 19 on Plate XX.

Typical details of the crane gantry, showing the reinforcement, are given in Figs. 20 to 23 on page 265. The crane beam is 3 ft. 6 in. wide and carries the roof stanchions on the centre line, the crane rails being bolted down on either side of them. All reinforcement consists of plain bars bent to form as may be required. The crane beam is, in general, reinforced with bars at the top and bottom faces connected by vertical tie bars, which are bent to hook form and embrace the upper and lower reinforcement. Heavier diagonal members are also introduced, as shown in Figs. 20 and 21. A plan and elevation and sections to larger scale, showing part of the reinforcement rather more clearly, is given in Figs. 33 to 35 on the present page.

As this reinforced-concrete continuous beam is 850 ft. long, the total expansion which had to be allowed for is considerable, and expansion joints have been introduced in each length of 850 ft. Details of one of these joints, showing the reinforcement, are given in Figs. 36 and 37, subjoined. As will be seen from Fig. 37, the joint is stepped, and the method of reinforcing the overhanging end portions of each section is clearly shown in the figures. The two parts are kept in register by means of $1\frac{3}{8}$-in. diameter bars embedded in one part of the beam and sliding in the other. The sliding action was ensured by heavily greasing the end of the bars before the concrete was cast round them.

Details of the arch which carries the crane gantry over the 75-ft. cross-aisle are given in Figs. 25 to 32 on page 265. The actual arch has been made comparatively light in order that the width of its face

Fig. 33.

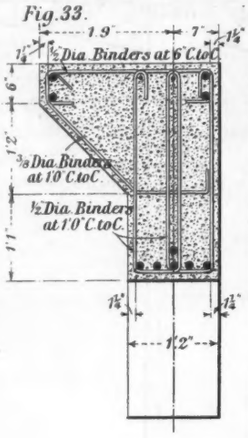


Fig. 34. DETAIL SHEWING PLACING OF STIRRUPS. BEAM S. B. 10.

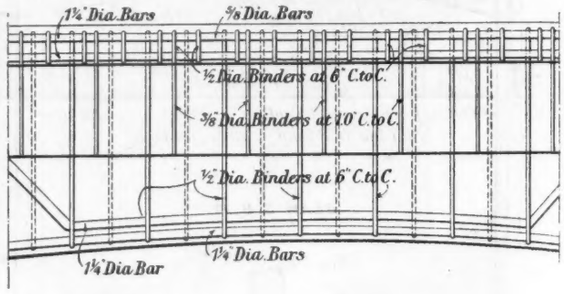


Fig. 35. PLAN.

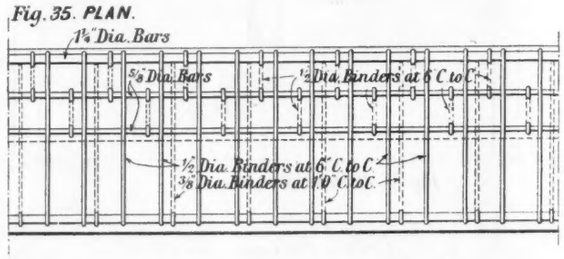


Fig. 36. SECTION X.X.

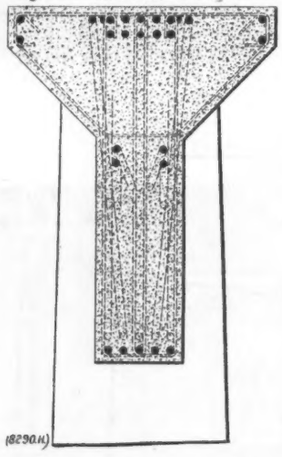
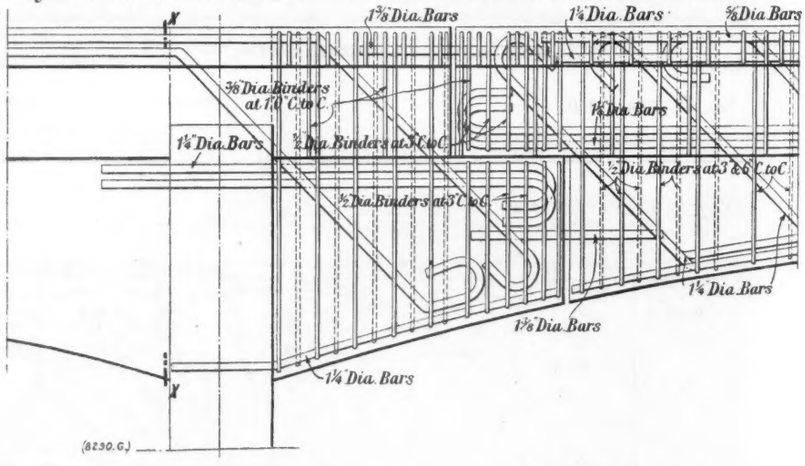


Fig. 37. ELEVATION SHEWING REINFORCEMENT AT EXPANSION JOINT. BEAM S. B. 12.


1⅜ Dia. Bars
1¼ Dia. Bars
⅜ Dia. Bars
⅜ Dia. Binders at 1'0" C to C.
1¼ Dia. Bars
1¼ Dia. Bars
½ Dia. Binders at 3" C to C.
½ Dia. Binders at 3" C to C.
½ Dia. Binders at 3" C to C.
1¼ Dia. Bars
1⅜ Dia. Bars
1¼ Dia. Bars
(8290.G.)

may conform generally with the width of the main columns as seen from the aisle. This effect will be appreciated from Fig. 15, from which it will be realised that a heavy arch would not have preserved the general proportions. The dimension across the face of the columns is 1 ft. 4 in., and the face of the arch has been made 1 ft. 1 in. wide. Comparatively slender proportions having been adopted for the arch, additional strength has been obtained by filling in the panels between it and the crane beam with 7-in. walls. These walls are reinforced and form an ntegral part of the arch structure, not being mere screen walls. The final effect is that the arch portion of the gantry structure is equally strong with the rest. It will be seen that no taper has been given to the columns on the side facing the bays. The columns and crane beam form a monolithic structure of great stability in a longitudinal direction, and as the only important force acting in that direction is that due to the movement of the overhead cranes, tapering of the columns is not required either from a structural or an architectural point of view. The columns are tapered in the other direction as bending moments cantilevers of similar construction formed in one with the columns, as shown in Figs. 30 and 32.

The type of roof adopted for the 75-ft. crane bays does not require any detailed comment. As will be gathered from Fig. 10 in conjunction with Figs. 15 and 16, the principals are built up of steel angle sections, a light and graceful effect having been obtained by simple means. The stanchions carrying the roof are provided with bases 1 ft. square secured to the crane beam by bolts cast in the concrete. Each 75-ft. bay is built with ventilating louvres running the full length of the building, while the centre portion of the roof is glazed—this latter feature of the work having been carried out by Messrs. Henry Hope and Sons, Limited, of Smethwick, Birmingham. The lower portions of the roof are covered with asbestos tiles. The 50-ft. bays are all constructed with an interesting type of pre-cast reinforced-concrete roof principals, and to which we have already incidentally referred in connection with Figs. 30 and 32. This type of roof is also used to a considerable extent in the Palace of Industry, and we will deal with it in detail when we come to describe that building in the next section of this article. In closing this present section, we must express our indebtedness to Mr. E. O. Williams, B.Sc., A.M.Inst.C.E., who has been responsible for the design of all the work with which we have been dealing, for furnishing us with information and the drawings on which our description is based. We have also to thank Messrs. Sir Robert McAlpine and Sons, who constructed the building, for information and material, and the Exhibition Authorities for facilities placed in our way.

(To be continued.)

THE TREATMENT OF WATER FOR INDUSTRIAL PURPOSES.

A JOINT meeting of the Institution of Mechanical Engineers and the Chemical-Engineering Group of the Society of Chemical Industry, held in the lecture hall of the first-mentioned institution on Tuesday last, took the form of a symposium on the treatment of water for industrial purposes. The chairman, Mr. W. H. Patchell, president of the Institution of Mechanical Engineers, who was supported by Mr. J. A. Reavell, chairman of the Chemical-Engineering Group, first explained that the four papers presented would be read in succession and afterwards discussed together. He then called upon Mr. H. W. Coulson to read the first of the series of papers which was on the treatment

of condensing water. Mr. Coulson dealt with the treatment of circulating water with chlorine in order to prevent the formation of gelatinous deposits of vegetable matter and micro-organisms on the inner surfaces of condenser tubes. The author called attention to the loss of efficiency arising from such deposits and the trouble entailed by the necessity for removing them by frequently cleaning the tubes. He then described the "Chloronome" apparatus which has been developed by the Paterson Engineering Company, Limited, for the treatment of circulating water with chlorine, the gas being purchased in liquid form in steel cylinders and automatically mixed with the circulating water in the desired proportion by means of the apparatus. The results obtained at the Hackney power station, where the Chloronome system has been installed by Mr. L. L. Robinson, were referred to, but as we have already dealt with the results and also illustrated and described the apparatus in our issue of the 1st instant, on page 142, we must refer our readers to that article for further particulars.

The next paper, by Mr. B. Heastie, was entitled "General Methods of Water Purification for Industrial Purposes." It dealt mainly with the various methods available for the treatment of water for boiler feeding, although reference was made to the question of water purification for other industrial purposes. The author first referred to purification by distillation processes, describing different types of evaporators and comparing the results obtained with single-effect evaporators using high-pressure steam, and with single-effect and double-effect evaporators using low-pressure steam bled from a turbine at a pressure of 4·7 lb. per square inch absolute. The thermodynamic advantage of the last-mentioned type was clearly demonstrated. After dealing generally with the purification of boiler-feed water by chemical means, the author described the Kestner continuous blow-down system, which is extensively employed on the Continent, and called attention to its advantages. The zeolite process of water softening was also mentioned, and methods of purification by purely physical means, using the actions of heat, vacuum and electrolysis, were briefly compared. For the elimination of iron and manganese the author described the process of oxidisation by means of air and gave some results obtained by this process. He also dealt with the extraction of oil from feed water by simple filtration, chemical treatment and electrolysis.

The third paper, by Mr. J. P. O'Callaghan, on water purification for industrial purposes, we reprint in an abridged form on page 286 of this issue, and the remaining paper by Dr. T. P. Hilditch and Mr. H. J. Wheaton is given in full on page 287. The last-mentioned paper deals with water softening by means of a comparatively new base-exchanging material manufactured by Messrs. J. Crosfield and Sons, Limited, of Warrington, and known as "Doucil." These papers having been read, the chairman called upon Dr. H. S. Hele-Shaw to explain some recent developments in connection with his stream-line filter which has already been illustrated and described in our columns on pages 89 and 265 of vol. cxvi, and on page 625 of vol. cxv. Dr. Hele-Shaw first explained that the filter units consisted of 7,000 sheets of paper having an aggregate thickness of about 2 ft. The speaker stated that as each sheet contained 50 holes, each of which constituted a filter, the total number of filters in a unit amounted to 350,000, and added that three such units were now piled one on top of the other, with a perforated metal plate between them, in order to increase the rate of flow. The function of the metal plates, we gathered, was to prevent the buckling or crinkling of the paper sheets which would otherwise tend to occur in a single pile of great depth. He also mentioned that it had been found quite unnecessary to enclose the filtering sheets in any form of casing, as although the external edges of the sheets became moist no liquid could escape. Another point in the design referred to was the provision of a valve by which the direction of the flow could be reversed for the purpose of removing any solid matter retained on the sides of the passages during the normal direction of flow, and a fourth point mentioned was that the cast-iron header used to compress the sheets was formed with a removable cover to enable the passages through the filter to be easily cleaned by passing a rod through them. Finally, Dr. Hele-Shaw explained the means now provided for adjusting the pressure on the sheets to the correct value. For this purpose, specially designed spring washers are fitted on the bolts connecting the upper and lower headers, the washers being placed between the upper header and the nuts of the bolts. The extent to which the spring washers are compressed is, of course, an indication of the pressure on the sheets, and the amount of compression is measured by means of a tapered plate which is passed between the face of the header and a lug projecting from the end of the spring washer in contact with the nut. The edge of the tapered plate is graduated to read the pressure in fractions of a ton. A plant ordered for the removal of oil from boiler-feed water and capable of filtering 500 gallons per hour, was shown in operation although it was only supplied with clean water.

Mr. T. H. Adams, representing Sir Henry Fowler, of the L.M. and S. Railway, who was then called upon by the Chairman to speak, referred to the elimination of the corrosive tendencies of certain waters. Water derived from a tunnel, he said, had been used on a large scale by his company, and had been found to have a marked corrosive action on boilers, particularly locomotive boilers. This water proved on analysis to have the following average composition:—

	Grains per Gall.
Calcium carbonate	10·50
Magnesium carbonate	3·03
Magnesium sulphate	0·81
Sodium sulphate	9·87
Sodium chloride	2·56
Silica	0·76
Water not expelled at 130 deg. C., organic matter, &c.	2·97
	30·50
Alkalinity (calculated as calcium carbonate)	14·10
Hardness	14·77 deg.

The dissolved oxygen and CO_2 were not excessive, amounting to about 0·66 and 0·52 grain per gallon, respectively. The steel plates, stays and rods were so corroded as materially to affect the life of the boilers, and the efforts made to eradicate the trouble had not been completely successful. The Archbutt-Deeley intermittent softening plant—without the carbonating device—had been tried for about two years, without any real improvement resulting. A further test using an excess of lime above the amount required, for ordinary softening, *i.e.*, to about 3 deg. hardness and 4 grains alkalinity per gallon, was commenced, and gave better results. Later, a continuous water-softening plant was installed for the purpose of repeating the tests with excess of lime. The makers, at their own request, however, were allowed to try normal softening on lines laid down by them, but it was ultimately found that, while the boilers were cleaner and freer from scale, there was more corrosion of a localised character with the softened water than with the untreated water. The speaker would, accordingly, be glad if any explanation of the abnormal tendency of the water could be given. Mr. Adams also mentioned a case of the action of condensed water treated by a precipitation and filtration method for the elimination of oil, the reagents used being equivalent solutions of aluminium sulphate and sodium carbonate. The plant was effective for its original purpose, but the treated water proved corrosive, due doubtless, to the CO_2 set free by the reaction, between the chemicals. To cure this trouble, the speaker proposed to insert iron or steel baffle plates in the hot well, or, preferably, to fix a series of pieces of expanded metal, so as to offer a large surface on which the corrosive tendency could expend itself on a material easily and cheaply renewed.

Mr. W. MacNab, the next speaker, said he was interested in the subject as having had the privilege of starting the first lime-soda purification plant in this country—in about 1885 or 1886. At that time, the water was simply mixed with lime and caustic soda, separation being effected by sedimentation. By this means results were obtained which were quite as good as were given by modern plant. He was struck by the excellence of the modern devices for measuring the quantities of reagents, so as automatically to follow any variation in the quantity of water used. This was not easy in the early days, but when the flow was uniform, excellent results were obtained.

Lieut.-Col. F. G. Hill, who continued the discussion, referred to the operations of his company in America, in connection with a plant for chemical precipitation and sedimentation followed by filtration. By the introduction of a Dorr thickener, or clarifier, between the mixing chamber and the sedimentation basins, several advantages were obtained, among which he mentioned reduction in the size of the sedimentation basins, quick return of sludge from the clarifier (with consequent saving of chemicals and better coagulation), and elimination of incrustation of the sand grains in the rapid sand filter. The detention period in the clarifier was about an hour, and 90 to 95 per cent. of suspended solids had been removed by this method.

Miss Snowden, representing Mr. W. B. Parker, of the British Thomson-Houston Company, asked if it were the present practice to determine the hardness by means of soap solution or by the method of acid titration. She had found in laboratory tests that the lime-soda method occasionally gave results which did not agree with results obtained in practice, and inquired as to the reason for this. The speaker also asked what was the most favourable temperature at which the reagents should be added. Referring to water with a good deal of both temporary and permanent hardness, about 20 parts of each, she inquired if the temperature were much below that at which the calcium bicarbonate would naturally decompose and precipitate the calcium carbonate without the addition of any caustic soda or lime. Finally, the speaker asked what methods were generally adopted for the estimation of free CO_2, bicarbonate and total CO_2 in water.

Mr. R. Stewart, the last speaker in the discussion, dealt with the softening of water by means of barium carbonate. In softening by the lime and soda process, he said, the purified water contained all the soda derived from the material used in the treatment. In industries like brewing and sugar refining the presence of soda or alkaline salts was not admissible. In such cases he recommended the use of barium carbonate for the removal of calcium and magnesium sulphates. An exchange took place of the bases and acid radicles, the precipitate formed consisting of barium sulphate and calcium carbonate or magnesium carbonate. By careful handling of the barium process it was possible to obtain a water that, for many purposes, might replace distilled water. For various reasons the progress of the barium process, introduced in 1902, had been impeded, but Messrs. B. Laporte, Limited (the speaker's firm), and Messrs. Royles, Limited, of Irlam, were collaborating, and there was every prospect of an improved form of plant for working the barium process being put forward.

Mr. B. Heastie alone among the several authors had any reply to make to the observations of speakers. He referred to the boiler corrosion question raised by Mr. Adams. His firm (the Kestner Company), the speaker said, had put upon the market an apparatus in which manganese steel shavings were used, and the water was passed through these, with the result that the oxygen content was reduced from 5 to 6 c.c. per litre to less than 0·1 c.c. per litre. This treatment had effected a complete cure in cases of boiler corrosion, the corrosion having been caused by oxygen in the feed water.

At the request of Mr. O'Callaghan, Mr. Newton then replied to the questions asked by Miss Snowden. The determination of hardness, he said, was made by calculation from the lime and magnesia found by analysis. Hardness determinations with soap, he added, gave the total hardness, while titration with acid gave the temporary hardness. With regard to the estimation of free carbonic acid, the method which the speaker used was to take a measured quantity of the water and add mixed barium and ammonium chlorides and a measured quantity of barium hydrate. This was allowed to stand over night and the residual barium hydrate was titrated with acid in the morning.

The Chairman then invited Mr. Reavell to propose a vote of thanks to the authors of the papers, and when this had been carried, the meeting terminated.

WOOD-WORKING MORTISING AND BORING MACHINE.

CONSTRUCTED BY MESSRS. WADKIN AND CO., ENGINEERS, LEICESTER.

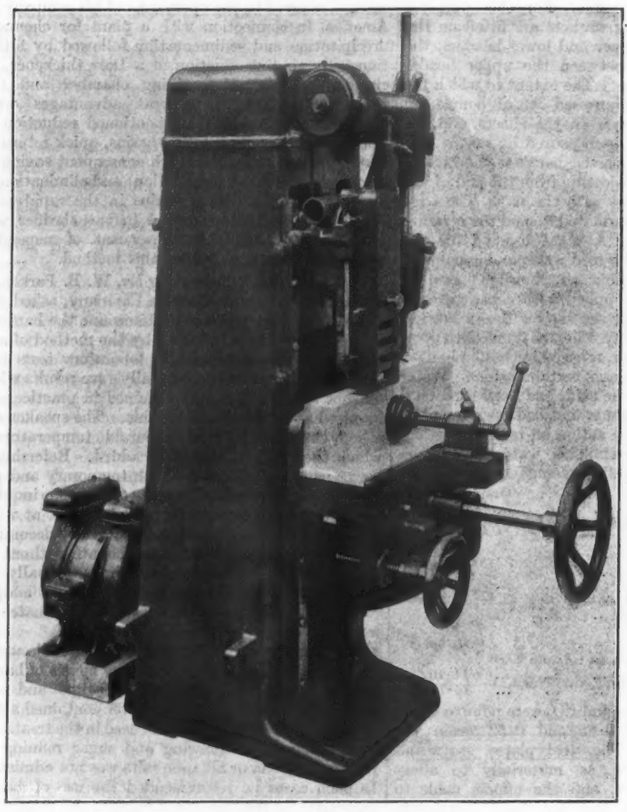


FIG. 1.

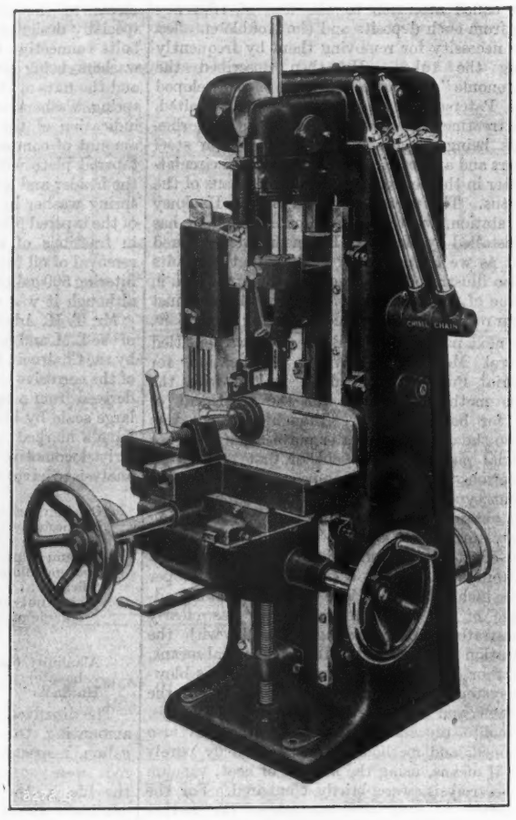


FIG. 2.

A COMBINED chain and hollow chisel machine for mortising, which can also be used for boring, is shown in the accompanying illustrations. This machine is one of the products of Messrs. Wadkin and Co., of Green-lane Works, Leicester, in the design of which they have introduced many distinctive features. The tools immediately stop running when they are withdrawn from the work so that adjustments and the setting up of new jobs may be effected under perfectly safe conditions for the operator. The guard, which is hinged so that the chain may be inspected when necessary, completely surrounds the chain and rests upon the top surface of the timber when the machine is in action. Another improvement which has been incorporated in the design is that the table is raised or lowered by the use of a conveniently placed handwheel instead of the old arrangement of having it on the screw below the table. The machine will take timber of sizes up to 12 in. by 8 in. cross section and will give a maximum size of mortise, when using the chain, of 1¼ in. by 3 in. and of 6 in. depth. The maximum capacity of the chisel side of the machine varies with the dimensions of the hole, and mortising can be carried out to a depth of 3¼ in. for holes up to ⅜ in. square and to one of 5½ in. for sizes between that value and 1 in. square.

The general layout of the machine is clearly indicated in the illustrations, and it will be noted that the headstocks for the two cutter systems are mounted on shoes, which are situated side by side on the front of the heavy main frame. The drive to these is taken from either a belt on a fast and loose pulley or directly from an electric motor as is shown in two of the illustrations, Figs. 1 and 2. From the shaft of either system a single belt is used to transmit the motion to both the chain and the chisel headstocks. This drive is enclosed within the main body frame but is readily accessible through large panels on the back of the machine. The transmission is effected through cone friction clutches which make possible the automatic stopping of the motion immediately the tools are withdrawn from the timber. This action is very desirable, not only on account of the safety of the operator which it ensures, but because of the reduction effected in the wear and tear. The chip breaker is designed to prevent any tendency to break the top edge of the mortise. Adjustable stops are provided on the headstock slides to restrain the tool when the intended depth is reached. The levers for the two systems are situated side by side in a position where they may be easily operated by the machine worker. In both cases the headstocks are operated through machine-cut steel racks and gun-metal wheels. A fan is installed to take the chips clear of the machine when working. Easy running of the entire system is ensured by the use of ball bearings.

The table has a double movement, of which the cross tranverse is operated by handwheel and screw and the lateral movement by a rack and pinion. The work is held in place by a powerful lever cramp which can be locked in position when set. Protected bevel gears are used to obtain the required transmission of motion to raise and lower the table, the weight of which is taken by a ball thrust washer. In the equipment supplied with the machine there is a small grinder with which the teeth of the chain may be kept in good cutting condition. Boring may be performed with the machine by substituting a boring bit for the hollow chisel auger, and holes may then be made with it up to 1½ in. diameter and 8 in. depth.

THRUST BLOCKS FOR THE SS. "EMPRESS OF AUSTRALIA."

THE SS. Empress of Australia, which belongs to the Canadian Pacific SS. Company, is one of the vessels delivered by Germany to the Allies under the treaty of Versailles. She was launched under the name of Tirpitz, and was fitted with turbines driving the propellers through Föttinger gear. Her designed speed was 17 knots, but she was unable to develop anything like this speed owing to continuous trouble with the turbine thrust blocks. The blocks in question are represented in Figs. 1 to 5 on page 272. There were, it will be seen, three horseshoe thrust collars each fitted with elaborate arrangements for water cooling. Forced lubrication was adopted, and both the fixed and running collars were deeply grooved in the endeavour to ensure a full and uniform distribution of the lubricant. The arrangement of the grooving on the moving collars is clearly shown in Figs. 3 and 4, whilst Fig. 5 shows how the oil was led into the grooves on the fixed collars. The bearing surfaces of the latter were of white metal. The estimated thrust was 50,000 lb. and the mean rubbing speed 88 ft. per second, and if full speed could have been reached the revolutions would have been 830 per minute.

As stated, however, nothing approaching full speed could be maintained, and the question arose as to whether entirely new thrust arrangements would have to be installed; or whether it would be possible to modify the existing thrusts to meet these abnormal conditions. The first alternative was negatived on account of the great cost involved, the thrust collars being integral with the turbine spindle, and the thrust block being incorporated in the turbine casting. The problem was accordingly referred to Messrs. Michell Bearings, Limited, of South Benwell, Newcastle-on-Tyne; and, in collaboration with the technical staff of Canadian Pacific Steamships, Limited, designs were prepared to instal a modified form of the now well-known Michell thrust, utilising the existing thrust shaft, and fitting into the existing housing.

It is, of course, always a more troublesome problem to correct an imperfect design than to make a good one *ab initio*. The owners naturally wished as much of the existing parts to be incorporated as was practicable, and a certain amount of experimenting had accordingly to be faced before fully satisfactory results were obtained. The difficulty lay in ensuring a full supply of oil. The Michell bearing is, of course, very economical in oil, requiring much less per annum than the ordinary collar thrust, but the supply must be ample at all times and provision made to ensure that each block gets its due share. The housing as fitted in the ship was, however, of a design that made the attainment of this desideratum a matter of great difficulty. The existing casing could not in fact be made oiltight, and in the end an inner casing had to be provided, which enclosed the new thrust block. Thus equipped the ship reached her designed speed and has now been

WOOD-WORKING MORTISING AND BORING MACHINE.

CONSTRUCTED BY MESSRS. WADKIN AND CO., ENGINEERS, LEICESTER.

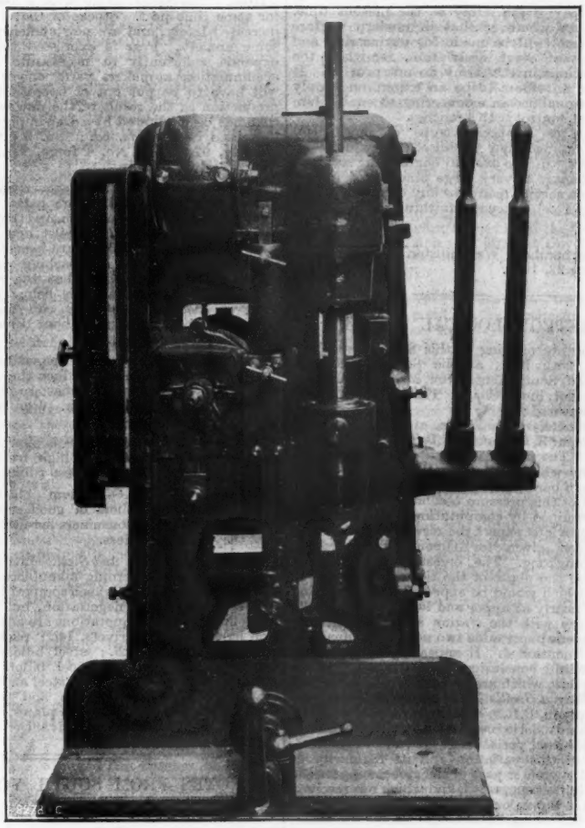


FIG. 3.

running regularly between Vancouver and Hong-kong for about 18 months.

The new bearings are represented in Figs. 6 to 8. As will be seen the whole load is now taken on a single collar, and to find room for the standing component one of the collars on the existing shaft was turned off. This component is secured in place by steel keys which are best seen in Fig. 7, and it is also bolted to the housing through brackets as shown. The water-cooling system has been eliminated. The oil supply enters by the pipe shown at the top and is distributed as indicated in Fig. 8. The inner oil casing is represented by *aa*, Figs. 6 and 8. It is provided with baffles abutting on the shaft as indicated at *bb*, Fig. 8, which are sufficiently tight to ensure that some portion of the oil overflows at the top as represented in Fig. 8. By this means the blocks run thoroughly drowned in oil.

As shown in Fig. 6 the Michell pads extend round the whole circumference. The two upper Michell pads are mounted on a loose section which is secured by the bolts *cc*, Figs. 6 and 7. On removal of these the lower section can, on loosening the keys and removing the securing bolts and clamps, be swung round and lifted clear of the shaft.

The block is required to take thrust in one direction only, but as will be seen in Fig. 8 provision is made to take a momentary load in the reverse direction by the surging ring shown. The thrust on the block is the difference between the steam thrust on the turbine and the thrust on the driving component of the Föttinger gear. In Fig. 9 we reproduce a photograph which shows the Michell collar with two of the pads in the foreground. The component shown to the left is the stop which prevents the pads from moving round in their supporting ring. It is shown in place at the top of the photograph of the collar.

PERSONAL.—The Consolidated Pneumatic Tool Company, Limited, inform us that the address of their Cardiff office for the future will be 18, Bank Buildings, 98 St. Mary-street, Cardiff.

SOCIETY OF GLASS TECHNOLOGY.

AT the meeting of the Society of Glass Technology in Sheffield on February 20, two sessions were held. In the morning there was an exhibition and demonstration of modern pyrometers at the Department of Glass Technology of the University. The following firms exhibited:—(1) The Power Instrument Company, Limited; (2) The Cambridge and Paul Instrument Company, Limited; (3) The Foster Instrument Company; (4) The Optical Pyrometer Syndicate; (5) Messrs. Booth and Miller also demonstrated their New Temperature Controller. At the afternoon session the subject under discussion was "The Use of Pyrometers in Glass Works." Five papers were presented and of these abstracts are subjoined:—

1. *The Use of Pyrometers in Glass Works*, by E. A. Coad-Pryer, B.A. The value of pyrometric equipment in a glass factory depended essentially on three factors:
   1. The reliability of the pyrometer itself, particularly the clock-work;
   2. The skill which is expended on its maintenance; and
   3. The attitude with which the management, foremen and furnace operators regard the pyrometer.

   Of these three the last was regarded as the most important. The pyrometer in no way displaced the trained eye; its real function was to supply further information in order that a highly-skilled operator might be able to get more out of his plant than had hitherto been possible. The range of temperatures to be measured could conveniently be subdivided into three groups:—
   1. The range 0 deg. to 700 deg. C., covering lehrs, stack temperature, produce and gas, &c.
   2. From 700 deg. to 1,200 deg. C., regenerator temperature, pot work, and
   3. Above 1,200 deg. C., the temperature of the melting furnaces.

   In the first group the thermo-couple was the most convenient instrument to use. Some sort of a portable thermo-couple should be part of every works equipment. A convenient couple for low temperature work was iron-constantan, the wire to be about 22 gauge.

   In the high temperature ranges an optical or total radiation pyrometer was, as a rule, the most convenient. The tank furnace might be subdivided into 3 zones; the melting zone, the plaining zone, and the refining end. Two permanent pyrometers should be used on each furnace, one on the refining end, the other sighting through a hole in the end wall at the melting end of the furnace. The use of couples embedded in the wall of the tank or in the crown caused probably more trouble than they were worth.

   The optical or radiation pyrometer, if used with discretion, was the most reliable and the most easily applied. The author's experience was that the optical instruments gave less variable readings than did the radiation instruments. The all-important factor with any installation was the training of the staff and operators to use the instruments with intelligence as an aid to the maximum efficiency in furnace manipulation. A bibliography was added to the paper.

2. *Continuous High Temperature Measurements in Glass Works.* By W. M. Clark, Ph.B. (U.S.A.) In the strictest sense of the term there was probably no absolutely accurate method existing for constantly determining glass-house temperatures. We could only approach this desirable aim by refinements of installation and careful maintenance, and this meant both equipment and maintenance expense. Therefore, in considering the subject of a pyrometer installation the glass manufacturer must balance the factors of what his demands for accuracy will be worth against the initial and operating costs of various systems. It is always advisable to install both the indicating and recording type of instrument, side by side.

   Experience of a number of modern well laid out plants showed that pyrometric measurements were reflected in the cost sheets. The morale of the furnace men was improved by eliminating the human errors of judgment in guessing at temperatures and cost per unit of output decreased. With improvements in pyrometric equipment the tendency was for their more extensive use around glass works. The depreciation on such equipment was not excessive, about 10 per cent. per annum being a fair amount, judging from successful installations, and as improvements came along they could be incorporated into the system, replacing features which became obsolete and thus keeping the installation up-to-date. A well-planned system would reduce overall costs in a year more than sufficient to pay for the investment and often would leave several times this amount if used intelligently.

   The most forceful argument for the adoption of pyrometer control in a glass works was on the score of economic savings, but the information thereby made available to the management and staff was also important in showing each man a tangible effect of his operation on the thermal conditions. The producer man saw that good gas was necessary to maintain temperature, the furnace man saw the result of proper draught regulation, the foreman of the finishing department could be satisfied whether the ware was being properly annealed, and the whole schedule of production was benefited.

3. *Recent Advances in the Design of Temperature-Measuring Instruments, &c.* By H. W. Whipple, F.Inst.P. One difficulty in connection with disappearing filament pyrometers was to get two lamps which would be interchangeable. Methods for overcoming this difficulty were indicated. The speaker then said how greatly he had been impressed with what he had seen recently in the United States in the matter of automatic temperature control. He understood considerable work was being done in this connection in glass works, and referred to the works of Messrs. Keuffel and Esser when lehr temperatures were controlled from 200 deg. C. to 600 deg. C. For every kind of glassware a special cooling curve was followed. In the United Kingdom automatic temperature control was being developed. The main principle in such control was a galvanometer needle which was deflected by some method. Lantern slides were then exhibited, showing various forms of controller including (1) Brown, (2) Bristol, (3) C. Engelhard, (4) Leeds and Northrup, (5) Cambridge, (6) Barr, (7) Althorpe. It should be possible to control lehr temperatures by some such automatic control apparatus, and so to lessen the worries of the works manager.

4. *Practical Application of Pyrometers to Glass Works.* By C. E. Foster, F.Inst.P. Both optical and total radiation instruments were calibrated for what were known as "black body" conditions, and when used on hot bodies which were not technically what were known as "black bodies," the reading would be in error by an amount which varied with the actual condition. An ordinary large glass melting tank was by no means a "black body." The author suggested that luminous gas flames might have the power of selective emission, that is, they radiated a light which was not in proportion to their temperature, but might be of an intensity which would correspond to the brightness of a solid hot body at a much higher temperature. Considering a surface of molten glass, viewed obliquely in a furnace that did not realise "black body" conditions, it obviously had a considerable reflecting power, but he found that its reflecting power as experienced in measuring with a total radiation pyrometer was relatively much less than the unoxidised surface of molten metal. Further consideration showed that this was reasonable because there was some considerable transparency in the glass so that it would actually omit a greater proportion of the heat from inside. Thus it was actually found that molten glass approached more nearly to a true "black body" than unoxidised molten metal.

5. *Reflections on Pyrometer Design.* By W. Bowen. Economy in fuel consumption, long life of furnaces or other heating devices employed, elimination of waste of raw materials and of irreparable losses of finished products all depend upon the raising of the heat-treated materials to no less, and no more, than the requisite temperatures. The value of Pyrometers to such heat-treatment problems was now too well recognised to need discussion. A few of the standards which a good pyrometer should fulfil were as follows:—(*a*) Simplicity of design and operation, (*b*) Robustness and freedom from

liability to breakdown under shock or accident. (c) Flexibility of apparatus to meet practical conditions. (d) Long and stable life of pyrometer. (e) Speedy response to temperature changes. (f) Automatic action (g) Accuracy. These standards were then discussed with reference to the new "Pyro" radiation pyrometer, an instrument compact in shape, extremely portable and simple in operation.

THE OPTICAL SOCIETY.

At the Annual General Meeting of the Optical Society held at the Imperial College on Thursday, February 14, 1924, the officers and members of council were elected to serve for the year 1924–1925.

At the Ordinary Meeting of the Society held after the Annual General Meeting, the following papers were presented and discussed:

(1) *The Addition of Aberrations*, by T. Smith, M.A., F.Inst.P. General expressions are found which give quantitative measures of the aberrations of a complex optical instrument in terms of the corresponding measures of its component parts. The systems considered are symmetrical about an axis but otherwise of a quite general character.

(2) *The Choice of Wave-Lengths for Achromatism in Telescopes*, by Lieut.-Col. J. W. Gifford, F.R.A.S. In correcting a combination of two glasses for chromatism, focal lengths for two colours of the spectrum are made equal. The outstanding error for other such colours is called the secondary spectrum. The object of the paper is to determine the effect on the secondary spectrum of varying the two colours chosen. These effects calculated by trigonometrical tracing are illustrated by graphs and tables.

(3) *A New Form of Corneal Microscope with Combined Slit Lamp Illuminating Device*," by E. F. Fincham. For the clinical examination of the cornea and anterior portions of the interior of the living eye, a procedure often necessary, a specially mounted microscope, monocular or binocular, is used in conjunction with a so-called slit-lamp. In the apparatus as used at present two instruments are separately mounted, and must be adjusted independently. The paper which is the outcome of some experiments made in the Department of Applied Optics of the Northampton Polytechnic Institute, London, upon the microscope examination of the living eye, describes a combined instrument in which the adjustment is common to both the microscope and the lamp, thus greatly facilitating the observation.

(4) *The Troughton Dividing Engine*, by David Baxandall, A.R.C.S. The actual description of this machine, which is now housed in the Science Museum, South Kensington, was preceded by a reference to the dividing engines of Henry Hindley of York (1740), of the Duc de Chaulnes (1768) and the first engine (1766) of Jesse Ramsden. Ramsden's second engine (1775) for which he received the reward from the Commissioners of Longitude, and which is now preserved in the National Museum at Washington, was also referred to.

After mentioning John Troughton's engine (1778), those of Edward Troughton (1793) and of William Simms (1843) were described, and it was shown that the engine exhibited was the original engine of Edward Troughton, with the self-acting mechanism of William Simms added in order to make it automatic in action. The engine has been in use almost continuously from 1793 until a year or two ago, though superseded for more accurate division by better engines constructed by the owners at different periods. The engine was shown in operation by Mr. George A. Mitchell, of Messrs. Cooke, Troughton and Simms, Limited.

The French Military Expenditure.—The Paris journal, *Le Moniteur de la Flotte*, compares together the sums proposed for expenditure in 1923-24 on military purposes in the United States, Great Britain and France. The total expenditure estimated for the United States is 708,970,650 dols., equal to 3,544,853,270 francs at the rate of 5 francs per dollar, the detail figures being: war, 336,347,200 dols.; navy, 359,997,250 dols.; aviation, 12,626,200 dols. For Great Britain and the Dominions, the total is 189,067,77*M.*, which, at the rate of 25 francs, gives 4,726,694,475. For France, the total is 4,595,002,335 francs, and the detail figures show: war, 3,566,765,327 francs; navy, 1,028,237,008 francs; the figure for aviation being included in the sums for war and for the navy.

International Conference on Applied Mechanics.—The provisional programme for this Conference which will be held at Delft, Holland, in April next, has just been announced by the promoters. The proceedings will open at 8 p.m. on Tuesday, April 22, and the following day will be devoted to a general discussion on the theory of elasticity and related subjects. Sectional meetings will be held on Thursday, April 24, and on Friday, April 25, there will be a second general meeting devoted to the subjects of hydrodynamics and aerodynamics. After sectional meetings in the morning of Saturday, April 26, the Conference will conclude with a general meeting in the afternoon, while later the members have been invited to attend an ordinary meeting of the Nederlandsche Natuurkundige Vereeniging. The last item in the programme is a visit to Messrs. Philips' electric-lamp factory at Eindhoven and to the laboratory adjoining it, which visit will take place on Monday, April 28. Further particulars of the arrangements can be obtained from the Secretary, Prof. Dr. J. M. Burgers, Labatorium voor Aero en Hydrodynamica der Technische Hoogeschool, Nieuwe Laan, 76, Delft, Holland.

MECHANICAL ENGINEERING IN THE ARMY.

To the Editor of Engineering.

Sir,—Your leading article in Engineering of February 1, on "Mechanical Engineering in the Army" brings out very clearly the conditions of mechanical engineering services in the Army at the present time. There is no doubt whatever that in modern warfare very great demands will be made for engineering and technical services of every description, for which the existing organisations in the Army do not provide. It is impossible for an officer to be an expert on supply of food and also qualified in engineering to enable him to administer and control both branches.

The formation of a special corps of mechanical engineers self-contained and organised throughout by qualified engineers, to take over all engineering services, will save the country a very large amount of money and will produce a service ready for any emergency.

I am, Sir, yours faithfully,

W. E. Donohue.
(Col. ret.)

4, Queen Anne's-chambers, Westminster.
February 23, 1924.

ROYAL METEOROLOGICAL SOCIETY.

The usual monthly meeting of this Society was held on Wednesday, 20th inst., at the Society's Rooms, 49, Cromwell Road, South Kensington, Mr. C. J. P. Cave, M.A., J.P., President, in the Chair. The following papers were read and discussed:—

1. *The Lunar Atmospheric Tide at Mauritius and Tiflis.* By Professor S. Chapman, F.R.S.—The following is an abstract: "The moon is known to produce a tide in the atmosphere which reveals itself by a small semi-diurnal variation of barometric pressure during each lunar day. The range of this pressure oscillation is small, and can only be determined by computation from long series of records. In previous papers the results of such calculations have been given for Greenwich, Aberdeen, Batavia and Hongkong. The investigation has been continued because the phase of the tide is found not to have the value which would be expected (corresponding to high pressure nearly at upper and lower transit of the moon) but to vary with the station and also with the season. The present paper adds two new determinations to those already mentioned. It appears to be too early as yet to form definite conclusions as to the causes of the irregularities of phase which are revealed.

2. *The Semi-diurnal Oscillation of the Atmosphere.* By Professor S. Chapman, F.R.S.—This paper deals with the cause of the atmospheric oscillation which manifests itself in the semidiurnal variation of barometric pressure. The magnitude of this variation and its regularity of occurrence over the greater part of the globe, support the view which Kelvin first suggested, and which has received confirmation from the calculations of Margules, Hough and Lamb, that the oscillation is magnified by resonance, its period of twelve solar hours being in near agreement with a period of free oscillation of the atmosphere. It has remained an open question, however, whether the oscillation was mainly caused by the daily heating and cooling of the atmosphere, or whether the sun's gravitational influence also played an appreciable part in the phenomenon. This uncertainty rendered it difficult to explain, even roughly, the observed phase of the oscillation. In the present paper an attempt is made to estimate the relative importance of the two causes, assuming that the semidiurnal changes of temperature in the lower atmosphere are mainly due to the thermal conduction upwards from the ground. The result is somewhat indefinite, not because of mathematical difficulties, but chiefly owing to the scarcity of reliable data concerning the semi-diurnal variation of temperature, and the eddy conductivity, over large parts of the earth. It seems not unlikely however, that the sun's thermal and gravitational influences are about equally responsible for the oscillation, and on this hypothesis the observed phase of the oscillation can be accounted for fairly well. The magnitude of the oscillation indicates that the approximation of the adjacent free period to twelve solar hours must be very close, that is, to within a few minutes: this is much nearer than existing theories of atmospheric vibrations can account for.

3. *The Relationship between Current and Wind.* By C. S. Durst, B.A.—A large number of observations made by ships at sea are examined in the light of Ekman's theory of ocean currents. It is found that the theory is borne out by the average direction of flow, and that the average velocity of current is directly proportional to the speed of the wind. From Jeffrey's work on the theory of turbulence as applied to the ocean, coefficients of turbulence are deduced for various regions of the seas.

Forthcoming Mining Examinations.—An examination for first- and second-class certificates of competency as managers and under-managers of mines will be held on May 28 and 29, at Edinburgh, Newcastle-on-Tyne, Sheffield, Wigan, Cardiff, and Birmingham. The written part of an examination for certificates of qualification as surveyor of mines will be held at the same centre on May 29, 1924. Applications for the necessary forms should be made not later than March 31. In order that the appropriate forms may be sent, it is important that candidates should state whether they have already sat at one or more of the Board's Examinations. Letters should be addressed to the Secretary, Board for Mining Examinations, Mines Department, Dean Stanley-street, Millbank, London, S.W. 1.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

The Cleveland Iron Trade.—With the termination of the dockers' strike there is hope of resumption, to some extent, of export trade, but the market is still very unsettled. The statistical situation is less satisfactory than for some time past. Stocks of Cleveland pig-iron have increased lately, and are now sufficiently large to cause some anxiety. Fear is expressed that unless demand expands sufficiently to necessitate withdrawals from accumulations at makers' yards, one or two blast furnaces will have to be put out of operation. Falling cost of production as the result of the downward movement in coke has been followed by a drop in pig-iron prices. No. 1 Cleveland is now 97*s.* 6*d.*; No. 3 g.m.b., 95*s.*; No. 4 foundry, 94*s.*; and No. 4 forge, 93*s.*, all f.o.t. makers works, and f.o.b. Tees.

Hematite.—Values of East-coast hematite are easier, but in this branch makers are better situated than are producers of Cleveland pig-iron, and they are disinclined to make price concessions. Whilst new contracts are not readily arranged, and firms are keen to secure orders to follow on work rapidly approaching completion, they are reluctant to acknowledge that the recognised market price for Nos. 1, 2, and 3 is below 101*s.* Customers, however, declare that they can make purchases of mixed numbers at round about 100*s.* No. 1 is at a premium of a shilling.

Blastfurnaces Blowing.—A hematite furnace is going out for repairs which will reduce the number producing pig-iron on the North-East coast to 46, of which 12 are running on Cleveland pig-iron, 16 on hematite and 18 on other kinds of iron.

Foreign Ore.—Imported ore is slow of sale, consumers having good supplies, but high freights keep market quotations on the basis of best rubio at 24*s.* c.i.f. Tees.

Blastfurnace Coke.—Durham blastfurnace coke is weak. There are sellers of good medium qualities at 32*s.* 6*d.* delivered to consumers here who, however, report that they can buy at less.

Manufactured Iron and Steel.—Little news of moment is ascertainable concerning manufactured iron and steel. For foreign trade there is keen competition, and prices are a matter of individual negotiation, but for home business the following agreed quotations are adhered to: Common iron bars, 12*l.*; iron rivets, 14*l.*; packing (parallel), 9*l.*; packing (tapered), 12*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge, and tank plates, 10*l.* 5*s.*; steel angles and joists, 10*l.*; heavy sections of steel rails, 9*l.*; fish plates, 13*l.*; black sheets, 13*l.* 10*s.* to 13*l.* 15*s.*; and galvanised corrugated sheets, 18*l.* 15*s.*

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—The decision of the Government to build five cruisers will bring a certain measure of relief to the heavy trades at some distant date, but the general feeling among directors of armament concerns is one of disappointment. The vast plant maintained at East-end works is capable of a much larger output than can be represented by Sheffield's share of this undertaking even under the most favourable circumstances, and whereas the materialisation of the original intention to lay down a considerably larger number of these vessels would, directly and indirectly, have brought about the absorption of virtually the whole of over 20,000 unemployed, the most that can now be hoped for is a minor diminution in the ranks of the idle craftsmen concerned. Many of these expert workmen, tired of waiting for improved conditions, have already drifted to America, where most of them have found remunerative jobs. There is a very real danger that when business becomes more normal difficulty will be experienced in finding a sufficient supply of highly skilled labour to discharge the most intricate engineering operations. The dockers' strike did not last long enough to inflict serious injury on the general engineering sections, and prospects are believed to be fairly good providing further serious dislocation can be avoided. A healthy and growing demand for railway materials and furnishings, which is likely to last for years, is reported in the Sheffield Chamber of Commerce journal, which states there are many large foreign and Colonial schemes on hand besides considerable home railway extensions. The latter have been neglected since 1914, and the fear is expressed that when sufficient trade is available to employ fully the steel and related heavy industries, the railways will be unequal to the task of dealing with the traffic. The demand for tools, adds the Chamber, is distinctly expanding. Railway, marine, and general engineers are getting steadily busier. The house-building trade is also improving. Garden tools promise fairly well, and saws, picks and shovels are in better request. Files are healthier than for many months.

South Yorkshire Coal Trade.—Deficiency in the home demand for best steams is counterbalanced by a persistent call from Continental users. Collieries have suffered a far greater impediment from wagon shortage than from any dislocation resulting from the dockers' strike, and despite the strength of contract bookings, they are compelled to work irregularly so as to avoid undue congestion of output. The current surplus of cobbles and nuts is not unduly heavy, while slacks are moderately active. Business in house coal is rather less robust. Coke supplies are creating some anxiety among manufacturers, who fear a considerable rise in values during March. Quotations: Best handpicked branch, 35*s.* to 36*s.* Barnsley best Silkstone, 30*s.* 6*d.* to 32*s.*; Derbyshire best brights, 30*s.* to 32*s.*; Derbyshire best house

coal, 26*s.* to 27*s.*; Derbyshire best large nuts, 24*s.* 6*d.* to 25*s.* 6*d.*; Derbyshire best small nuts, 18*s.* 6*d.* to 20*s.* 6*d.*; Yorkshire hards, 25*s.* to 27*s.*; Derbyshire hards, 24*s.* to 25*s.*; Rough slacks, 12*s.* 6*d.* to 13*s.* 6*d.*; Nutty slacks, 10*s.* to 13*s.*; Smalls, 7*s.* 6*d.* to 9*s.* 6*d.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Movement in the Scottish steel trade is very limited at present, and is likely to continue thus until the labour outlook is clearer. Trouble in the coal trade and in the shipbuilding industry would completely block out any prospects of an early return to more prosperous times. But we must just wait and hope that sane counsels will prevail, and that any stoppage in these two important branches of industry will be averted. Orders now on hand do not amount to a large tonnage, and although inquiries all round are fairly good, buyers are very slow to fix up. The demand for shipbuilding material expands very slowly, but for constructional stuff there is quite a healthy outlet. Makers of black sheets could be doing with more business now as contracts on hand are gradually getting worked off. The general export trade is not opening out satisfactorily, and any lots on offer are very keenly competed for. Home prices are without change, and are as follows:—Boiler plates, 13*l.* 10*s.* per ton; ship plates, 10*l.* 5*s.* per ton, sections, 10*l.* per ton: and sheets 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—In the West of Scotland malleable iron trade a very quiet tone is only too general just now and many of the works are not very well off for orders. The bookings of late have not been heavy, and in most instances these have only assisted to stave off the evil day, but perhaps things will tend to improve in the near future. Inquiries would seem to point that way as quite a number have lately been in the market. Prices keep steady with "Crown" bars still quoted at 12*l.* 10*s.* per ton delivered Glasgow stations.

Scottish Pig-Iron Trade.—There has been little change in the state of the Scottish pig-iron trade over the week, and even the reduced output is more than able to keep pace with the demand. The latter is neither large nor steady, and should any heavy tonnage be asked for, the stocks on hand are quite sufficient to meet almost any calls that might be made. Consumers of hematite are doing moderately well with the result that furnaces are being kept going steadily. The demand is mostly against contract as new lines are not very numerous. The price is inclined to be the turn easier, but to-day's quotation is still 5*l.* 8*s.* 9*d.* per ton, delivered at the steel works. Foundry grades are not in very active request, and although the tone is rather weaker prices are being maintained at last week's level of 5*l.* 7*s.* 6*d.* per ton for No. 1, and 5*l.* 2*s.* 6*d.* per ton for No. 3, both on trucks at maker's works. The number of furnaces in blast, which was recently reduced by seven, will probably be still further reduced by other four next week.

Scottish Pig-Iron Shipments.—The dockers' strike was mainly responsible for the small shipment of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, February 23. The total of 267 tons was made up by 175 tons going foreign and 92 tons coastwise. For the corresponding week of last year the figures were 1,815 tons overseas and 55 tons coastwise, making a total shipment of 1,870 tons.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—In consequence of the strike of dockers and the diversion of shipping from the Bristol Channel, the quantity of tonnage available for coal loading has been so reduced that shippers with boats ready to take delivery can secure substantial concessions on the quoted prices. When the dockers' strike commenced there were nearly 400 vessels in the Welsh ports, but when work was resumed on Tuesday there were only 320, and of these 108 were held up, so that those actually in a position to take coal numbered just over 200. For shipment a week or more ahead sellers still firmly demand from 30*s.* to 31*s.* for best Admiralty large coal, and 20*s.* for best steam smalls, but for immediate loading will accept 1*s.* to 1*s.* 6*d.* per ton less. There is a good inquiry, and it is evident that consumers are anxious to secure stocks in view of the possibility of a miners' strike in April.

Dockers' Registration Scheme.—A scheme of registration was put into operation at Cardiff yesterday. The scheme which has been agreed by the Port of Cardiff Employers' Association and the Transport General Workers' Union provides that all men employed in loading and discharging ships, warehousing or general cargo work upon the docks, but excluding the permanent staff employed by the railway company, and other workers registered under the schemes, shall be registered. Each man is to be supplied with a member's registration card certificate and a tally bearing the same number as that on the certificate. The tally must be changed quarterly, and must be of a different design for each quarter. Men not in possession of the official tally will not be employed, and on being engaged a registered man must deliver the tally to the foreman or other employer. The tally is to be returned when the job or engagement is completed. A joint committee of representatives of the employers and men is to be established for the administration of the scheme, the expenses being shared jointly. The scheme in no way interferes with or alters any existing agreements.

NOTICES OF MEETINGS.

THE SOCIETY OF ENGINEERS (INCORPORATED).—Monday, March 3, at 5.30 p.m. in the apartments of the Geological Society, Burlington House, Piccadilly, W. Paper on "Development of Methods for the Collection of House (Domestic) Refuse." By James Jackson.

THE INSTITUTION OF MECHANICAL ENGINEERS: GRADUATES' SECTION, LONDON. Monday, March 3, at 7.0 p.m., in the Hall of the Institution. Annual lecture upon "Literature and Engineering." By Lieut.-Colonel E. Kitson-Clark, T.D., M.A., Member of Council. All classes of members of the Institution are invited.

INSTITUTE OF TRANSPORT.—Monday, March 3, at 5.30 p.m., in the lecture theatre of the Institution of Electrical Engineers, Victoria-embankment, W.C.2, when a paper will be read on "Air Transport and its Uses," by Mr. G. Holt Thomas.

BRADFORD ENGINEERING SOCIETY.—Monday, March 3, at 7.30 p.m. Meeting in the hall of the Bradford Technical College. Discussion on "Modern Developments in Electric Driving of Textile Mills," introduced by Mr. J. W. Longley, M.I.M.E.

INSTITUTION OF THE RUBBER INDUSTRY.—Monday, March 3, at 8 p.m., at the Engineers' Club, Coventry-street, W., when Messrs. Herbert Rogers, F.C.S, and B. D. Porritt, M.Sc., F.I.C., F.R.S.E., will read a paper entitled, "The Life and Work of Thomas Hancock" (illustrated with lantern slides). The chair will be taken by Sir Inigo Thomas, G.C.B.

THE INSTITUTION OF CIVIL ENGINEERS, NEWCASTLE-UPON-TYNE ASSOCIATION.—On Monday March 3, at 7.30 p.m., in the Lecture Theatre, Neville Hall, Newcastle-on-Tyne. Paper by Mr. T. H. Bryce, Assoc. M.Inst.C.E., on "Reinforced Concrete, Reservoirs and Water Towers."

THE CLEVELAND INSTITUTE OF ENGINEERS.—Monday, March 3, at 6.30 p.m., in the Hall of the Technical Institute, Corporation-road, Middlesbrough. Joint meeting with the Society of Chemical Industry (Newcastle Section) and the Institute of Chemistry (Newcastle and North-East Coast Section). Paper on "Engineers, and the Interpretation of Chemical Specifications for Iron and Steel, in Relation to Analytical Accuracy," by Mr. C. H. Ridsdale.

ROYAL SOCIETY OF ARTS.—Monday, March 3, at 8 p.m. Cantor Lecture: "A Study of the Destructive Distillation of Coal," by Edward Victor Evans, O.B.E., F.I.C., Chief Chemist and Products Manager of the South Metropolitan Gas Company, London. (Lecture II.) Tuesday, March 4, at 4.30 p.m.: Dominions and Colonies Section, "Empire Oil: The Progress of Sarawak," by the Hon. T. G. Cochrane, D.S.O. The Right Hon. Lord Bearsted will preside. Wednesday, March 5, at 8 p.m., Ordinary Meeting; "Building and Decoration of the War Cemeteries," by Major-General Sir Fabian Ware, K.C.V.O., K.B.E., C.M.G., C.B., Vice-Chairman, Imperial War Graves Commission. Lord Askwith, K.C.B., K.C., D.C.L., Chairman of the Council and a Vice-President of the Society, will preside.

THE INSTITUTION OF ELECTRICAL ENGINEERS: NORTH MIDLAND STUDENTS' CENTRE.—Tuesday, March 4, at 7 p.m., at the University, Leeds. Informal discussion, "Continuous Current, Single-phase, or Polyphase Supply for Electric Traction."

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 4, at 6 p.m. Papers to be submitted for discussion: "The Similarity of Motion of Water through Sluices and through Scale Models: Experiments with Models of Sluices of the Assuan Dam," and "The Measurement of the Discharge of the Nile through the Sluices of the Assuan Dam," by Harold Edwin Hurst, D.Sc., and David Alexander Fraser Watt. Students' Meeting, Wednesday, March 5, at 6 p.m. Paper to be read: "Cement Mortars," by Hubert Shirley Smith, B.Sc., and Charles Doveton Crosthwaite, B.Sc., Studs.Inst.C.E. Sir Cyril R. S. Kirkpatrick, Member of Council, will take the chair.

THE INSTITUTE OF METALS. NORTH-EAST COAST LOCAL SECTION.—Tuesday, March 4, at 7.30 p.m., in the Electrical Engineering lecture theatre, Armstrong College, Newcastle-on-Tyne. Discussion on "Alloys for Use with Superheated Steam," to be opened by Mr. H. J. Young.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, March 4, at 7.30 p.m., in the Rankine Hall, 39, Elmbank-crescent, Glasgow. Discussion on "Manœuvring of Ships. Part II.—Unbalanced Rudders of Twin-Screw Ships," by Mr. G. H. Bottomley. Paper "Efficiency in Ship Construction from the Strength Point of View." by Dr. J. Bruhn, will be read.

THE WOMEN'S ENGINEERING SOCIETY.—Tuesday, March 4, at 6.30 p.m., at the Samson Clark Lecture Hall, 57, Mortimer-street, W.1., a lecture will be given by Miss M. E. Phillips, on "Factory Legislation (Past, Present and Future)." The lecture will be followed by a discussion.

THE INSTITUTION OF SANITARY ENGINEERS.—Wednesday, March 5, at 7.30 p.m., at Caxton Hall, Westminster, a paper will be read dealing with "The Water Supply of Rural Districts," by Cecil H. Roberts, M.Inst.C.E., F.G.S.

THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—Wednesday, March 5, at 7 p.m., at the Engineers' Club, Coventry-street, London. Discussion on "Heating and Ventilation as applied to Ferro-concrete Buildings" will be initiated by Mr. A. Alban H. Scott M.S.A.

THE NEWCOMEN SOCIETY.—Wednesday, March 5, at 5.30 p.m., at Prince Henry's Room, 17, Fleet street, E.C.4, when the following papers will be presented: "The Rastricks: Civil Engineers," by H. W. Dickinson and A. Lee, members, London. "Memorandum on the Four Locomotives of the Delaware and Hudson Company, 1829," by L. F. Loree, M.Sc., member, New York.

THE INSTITUTION OF ELECTRICAL ENGINEERS: WIRELESS SECTION MEETING.—Wednesday, March 5, at 6 p.m. "Development of the Bellini-Tosi System of Direction-Finding in the British Mercantile Marine. By Commander J. A. Slee, C.B.E., R.N. (retired).

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 6, 1924, at 6 p.m. "Transmission Maintenance of Telephone Systems," by P. E. Erikson, member, and R. A. Mack, associate member. (Preceded at 5.30 p.m. by an exhibition in the Common Room by W. B. Sayers of apparatus to demonstrate "Magnetic Induction Attraction and Repulsion, especially among free and moving bodies").

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 7, at 7 p.m., at Storeys-gate, S.W.1. Informal meeting. Lecture on "Recovering Gold from the Laurentic." By Comm. G. C. C. Damant, R.N., retired.

ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, March 7, at 9 o'clock, a discourse will be delivered by Walter Rosenhain, D.Sc., F.R.S., on "The Inner Structure of Alloys." Afternoon lecture next week. Saturday, March 8, at 3 p.m., Sir Ernest Rutherford, F.R.S., on "Properties of Gases in High and Low Vacua" (Lecture I).

JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 7, at 7.30 p.m. at 39, Victoria-street. Lecturette, "An Introduction to the Study of Fire Danger in Factories, with some Notes on Fire Insurance," by P. M. Fraser, F.R.I.B.A.

THE INSTITUTE OF METALS. SHEFFIELD LOCAL SECTION.—Friday, March 7, at 7.30 p.m., in the Non-Ferrous Lecture Room of the University, St. George's-square. Paper on "Some Aspects of Alloy Plating," by S. Field, A.R.C.Sc.

HULL ASSOCIATION OF ENGINEERS.—Saturday, March 8, at 7.15 p.m., in the Municipal Technical College, Park-street. Lecture on "Examples on the uses of Reinforced Concrete in Marine Works and Pile Foundations subjected to Forces in various directions." By Mr. H. Forchhammer, M.Am.S.C.E. (U.S.A.), M.Ing.F. (Denmark).

THE LATE DR. ING. HERMANN DIETLER.—Dr. Hermann Dietler, who was for many years president of the Gotthard Railway, died in Zürich, on January 24, at the age of 85 years. Born at Breitenbach, Switzerland, on October 31, 1839, he entered the service of the Oron railway, between Fribourg and Lausanne immediately on leaving the Zürich Polytechnikum in 1860. When the Swiss Government decided upon granting a subvention to the Gotthard railway undertaking, then in a difficult position, and advised its reconstruction, Dietler was appointed one of the directors, and by 1882 the line was able to run a night service of express trains which was then a novelty for Switzerland. An acknowledged authority on railway construction and operation, he was a permanent member of the International Railway Congress, and was often consulted by foreign governments. He was also a member of the Federal educational council and took a great interest in the welfare of the Federal Technical High School, into which the Polytechnikum had developed.

MECHANICAL ENGINEERS IN THE ARMY.—In view of our recent article dealing with the position of mechanical engineers in the Army we are pleased to note that the opinions we expressed were strongly endorsed by General Sir Ian Hamilton in a speech before the British Legion at Southampton on February 26. From *The Times* report of his address, we observe that Sir Ian Hamilton urged that our new Army must be mechanicalised, but before this could be effectively carried out, the status and importance of the mechanical engineer must be recognised. The Navy, after a terrible fight, got their Chief Engineer brought up to the quarter-deck; from being a "greaser" he became an ocean swell. But in the Army the "greasers" were still battened down below hatches. They had no head of their own, either at the War Office or in the commands, corresponding, for instance, to the Director of Veterinary Services. The mechanical engineers were frittered away by driblets in the Army Service Corps, the Army Ordnance Departments, the Royal Artillery, the Royal Engineers, the Tank Corps, &c. They had no chief of their own or uniform of their own. There were everybody's children, and therefore no one of them was anybody's child. Yet they had to be the mainspring of the new model Army. They must be collected together into one corps. There must be a united body of experts, standing by to catch the ideas of men of science so as to work them out in metal. From the inside nothing was likely to be done. It was only human nature that the Director of Supplies and Transport should wish to go on repairing his own vehicles, and likewise the Director of Ordnance. But the day had come when the mechanical engineer must be given a chance to show his mettle; he must be allowed to stand on his own legs under his own engineer-in-chief, who would issue to the other departments exactly what assistance they required.

THRUST BLOCKS FOR THE SS. "EMPRESS OF AUSTRALIA."

(*For Description, see Page* 268.)

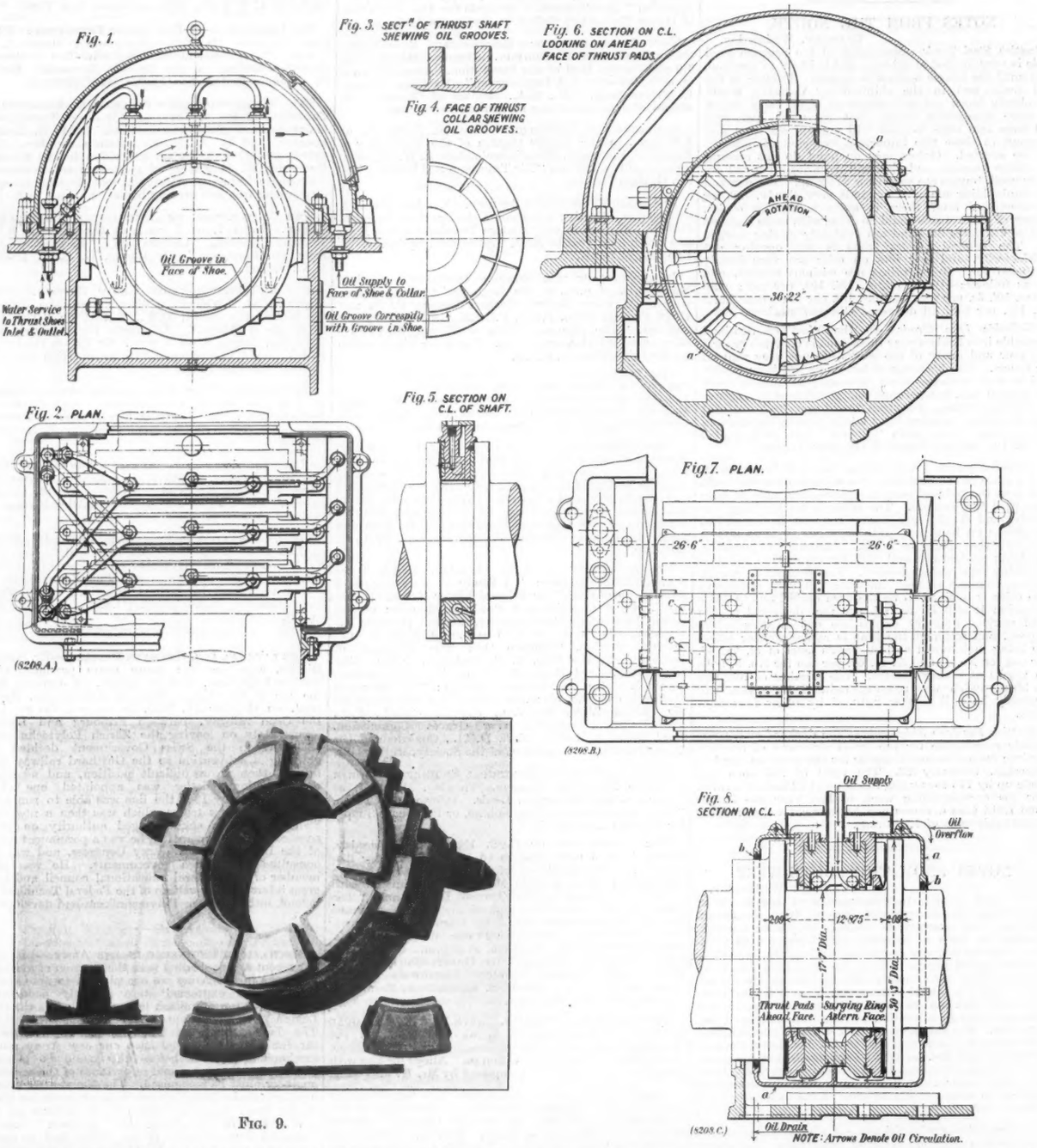


FIG. 9.

INSTITUTION OF CIVIL ENGINEERS.—The minutes of proceedings of this Institution, vol. ccxv and vol. ccxvi, for the sessions 1922–23, have now been issued in the usual form. The following papers, being original communications ordered by the Council to be published without discussion are now available, issued in strong cardboard covers: "The Deflections of Suspension Bridges," by J. W. Spiller: "The Experimental Development of an Automatic Integrating Intensity Rain-gauge, without Clockwork," by J. W. Meares; "A New Method for the Improvement of Existing Railway-curves," by W. H. Shortt, "The Estimation of Storm-water Discharge from Inhabited Areas," by G. S. Coleman; "The Mechanical Screening of Circulating Water and of Sewage," by H. Addison; "The Discharging Capacity of Side Weirs," by G. I. Coleman and D. Smith; "Evaporation by the Vapour-Compression Method," by T. E. Houghton; "Inchinnan Opening Bridge," by W. B. Hall; "Catenary Measurements," by R. Appleyard.

ELECTRICAL TRADES DIRECTORY AND HANDBOOK, 1924.—This directory, "The Blue Book," for the current year, the 42nd year of issue, will find the same welcome that was accorded to the preceding editions by all firms and private concerns who are interested in the provision and the use of electrical plant of all categories, both in this country, the Colonies and Dominions, the United States and other foreign countries. It contains information on patents, designs and trade marks in Great Britain and in foreign countries, mathematical and electrical data and figures, information as to tests, particulars on submarine cables, on the submarine laying and repairing fleets of the world, on wireless telegraphy, telegraph and telephone legislation and other legal notes, &c. There are five alphabetical sections covering British firms and persons engaged in electrical engineering both under names and specialities; Colonial, Continental and United States sections. The book has 1372 pages. It is published at the price of 25*s.* net, by Messrs. Benn Brothers, Limited, 8, Bouverie-street, London.

UNITED STATES NEW ARMAMENT.—A report in *Iron Trade Review*, Cleveland, Ohio, is to the effect that the American Ordnance Department has perfected an aerial bomb weighing 4,000 lb., ten times the weight of the largest bomb used in the world-war. It contains 2,000 lb. of explosives and is capable of making craters 150 ft. in diameter and 57 ft. deep. The bomb is 14 ft. in length. It has been manufactured to be carried in the Martin bombing plane, the two together forming the heaviest demolition units known. An ordnance tractor has been built in the United States to run at 30 miles an hour up a 45 deg. slope without difficulty, and capable of being sent through water up to the driver's chin. The new American 75 mm. gun has twice the range of the 75 mm. French gun used in 1918, and the re-designed 155 mm. gun outranges the French one by nearly 5 miles, whilst the new 4·7 in. gun outranges the pre-war American one two-and-a-half times and fires a heavy projectile. Newly perfected automatic shoulder-rifles bid fair to replace the magazine rifle of world-war days.

ENGINEERING.

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ENGINEERING.

FRIDAY, FEBRUARY 29, 1924.

PRODUCTION COSTS IN THE ENGINEERING INDUSTRY.

THE slight improvement in the outlook of the engineering industry, which made itself felt at the end of 1922 and which gave rise to so much optimism at the beginning of last year, did not materialise to the full extent expected. In the last few months of 1923, however, the general trend of improvement, which hung fire during the summer, seemed to be resuming way once more. It is not in any way suggested that a fatalistic view should be taken of this new improvement because the last one disappointed hopes, but it is suggested that it would be very easy to take too optimistic a view of the present situation. The principal reason for an optimism, unjustified by the facts of the situation, is that manufacturers have not yet quite got rid of pre-war conceptions. Before the war, slumps and booms followed one another in the normal fluctuation of trade and were of reasonably calculable extent and duration. The abnormal slump through which we have just been passing must clearly come to an end some day, but the speed with which the boom arrives and the extent to which it develops will depend on a due appreciation of the abnormal hindrances which are now operating to prevent it or to throttle it.

The one cause above all others of the present state of affairs is to be found in the decreased purchasing power of our customers at home and abroad. The only method of removing this cause which is within the control of the manufacturer, is to make prices more attractive. To some extent an improvement in the economic situation in Europe will stimulate the demand for British products, and it is the effect of such an improvement which is causing the present "boomlet." The natural tendency for the demand to increase from this cause will speedily be removed if it is met at once with a corresponding increase in our cost of production, and, therefore, selling price. Indeed, if the selling price remains stationary, it is probable that the demand will die out from the effect of fortuitous influences. It is, therefore, of supreme importance that every effort should be made at the present moment to reduce selling prices in order to encourage the tender plant of reviving demand so that it may be securely established by the operation of the snowball principle.

In order that this may not be deemed a counsel of perfection, it is proposed to examine the factors which militate against such a reduction of prices and to suggest in what direction efforts should be made to counteract them. It might be thought at first sight that an improvement in trade would carry with it immediately a reduction in the burden upon industry occasioned by expenditure upon the relief of unemployment. In pre-war days this would undoubtedly have been so, but at the present time it must be recognised that no such hope can be entertained in the near future. In the report by the late Minister of Labour on the Unemployment Insurance Scheme, it is stated that "the high rates of contribution from Employers will have to be maintained until the present debt of the unemployment fund has been paid off and any necessary reserve accumulated." Thus, apart from the advent of a Labour Government, no reduction in this direction is to be expected until the debt, it stands at present at 16,000,000*l*., is paid off and a reserve accumulated.

There are too many instances of a tendency for Members of Parliament of whatever Party to put the favour of their constituents in a future election in front of the interests of industry. A notable example of this was the recent Unemployment Insurance Bill, in which the gap system was approved without a dissentient voice in the House. Apart from the merits or demerits of this measure from other points of view, it means that the contributions which are at present in excess of the expenditure, and which might otherwise have been employed in reducing the debt will now be absorbed for the purpose of paying this additional benefit. The effect of a Labour Government in office may be felt in other ways, such as an increased expenditure by Local Authorities, an example of which may be found in the recent decision of the Minister of Health on the question of the Poplar surcharges. Quite apart from the gross cost from new legislation by the Labour Government there may be a general increase in the expenditure of all Government Departments from a more socialistic administration of existing legislation.

If we turn from this field to a consideration of the direct costs of production we do not find a very much more reassuring situation. There is ample evidence that prices of materials have reached rock-bottom and are, if anything, once more on the up-grade. It cannot be to a reduced cost of materials, therefore, that we must look unless this can be brought about by some reduction in the cost of transport. There is a widespread desire on the part of Labour to raise the general wage rate. Naturally, the impetus of this movement will be increased by any signs of a revival in trade. Yet another burden, which there does not appear to be any likelihood of reducing, is the cost of hiring capital. Reference here is intended more particularly to the interest on capital hired in the past rather than to the cost of obtaining it at the present moment. It is beyond dispute that the capitalisation of many firms is excessive inasmuch as the capital was obtained to a great extent at the highest period of inflation, and the subsequent deflation has appreciated the value of holdings, and thereby increased the standing charges on production.

Where then are we to look for savings in the cost of production? We are inclined to the view that the majority of firms are not in a financial position to expend money on more efficient appliances, even were they in need of new plant. It is rather to a more scientific utilisation of our existing resources that we must turn once again. It will be said, no doubt, that this doctrine has been preached *ad nauseam*, and that during the last few years every method of increasing efficiency, eliminating waste and organising production has been explored. In many cases this may be true, but it may also be true that after a serious effort to

achieve these objects a feeling may supervene that everything has been done that is possible, and that further attempts will be fruitless. It cannot be emphasised too much that there is always room for improvements in this direction, and that now in particular it is necessary to keep an open mind and an active watch upon this aspect of affairs, if for no other reason than that it is the only direction which is still available to us for making our prices more attractive.

With regard to wages in particular, since a gross reduction is out of the question, the problem is to seek in every way how a higher output may be obtained for the present wage bill. No hard and fast recommendation can be made on a subject of this kind, but it may be safely urged that every individual firm should not regard their present system of piecework, payment by results or other method of remuneration to be inevitable and unalterable for all time. The question of remuneration in industry is not a closed book, and an open mind brought to bear on the particular problems of each shop will still reveal a great scope for giving the incentives necessary to secure increased output without a serious increase in the total weekly wage bill.

There is also a large field of economy still waiting exploration from improved organisation and efficiency of our workshops. By this, extensive alterations in equipment and costly investigations with scientific apparatus are not implied, but a closer watch on small details. A considerable aggregate saving may be made in the year by means of more intelligent management and suspension of many works.

Yet another department to which attention might profitably be turned is that of materials. It has been said that no reduction in the price of materials is to be expected, but if prejudice is laid aside and vigilance is exercised with regard to the scientific developments of the day it may be found that a more expensive material, which will give adequate or even improved results may effect a saving in prices through reduced bulk required owing to superior strength or other qualities. In spite of the fact that many of the greatest scientific developments have been made in this country, foreign manufacturers have indisputably made greater use of them than those who, living in the country of their origin might naturally have been expected to take first advantage of them. Industry cannot look for much assistance from Parliament. It must look for salvation within its own borders.

THE PROBLEMS OF THE SHIPPING INDUSTRY.

The relationship between supply and demand is so well understood by thinking people, and the effect that it has upon the prices at which business is done is so much appreciated by those who have anything to do with trade, that it must seem unnecessary to make any comment on the actions involved. While that is perhaps so, there is no doubt that there is in existence quite a lot of misunderstanding in regard to industrial relations and the need for improved production, and there are people who are foolish enough to suggest the regulation of activity in a manner which they vainly imagine will be for the good of the community or, at any rate, of one particular section of it. Such efforts always end in disaster and add to the destruction of the fondest hopes of this type of irrational thinker. For this reason any endeavour must be appreciated which helps to clear away the mists from the minds of well-intentioned but loose-thinking people, who look for some early return of our industries to their normal state of activity by the operation of some pet scheme of interference with the natural operations of trade. In this respect the presidential address which Sir Alan G. Anderson delivered to the Chamber of Shipping must be considered as no mere statement to his associates of the conditions to-day in the shipping industry but as a message to all, of what supply and demand mean to some of our most important industries. The shipping trade is in a very precarious state, because of the excessive number of vessels which there are in the world, and the small demand for their services in conveying the limited supplies of goods available for overseas trade. When shipping is restricted shipbuilding is in small demand and all the industries associated with the supply of materials to the yards are also hard hit.

The only comfort Sir Alan said that he could give the shipping industry, was that the general freight position in 1923 was definitely the worst that could be. When the laying up of ships took place freights did not fall further unless expenses fell. There was still a redundant fleet of vessels in all countries ready at short notice to put to sea when freights did rise, but by flooding the market that would bring about an immediate lapse of freights. The total world's tonnage laid up in July, 1922, exceeded 9,000,000 tons gross, but had diminished to 8,000,000 tons at the end of the next twelve months. The rate of release of British tonnage had been much more rapid than the general experience, but there was still something like 1,000,000 tons gross laid up in January of this year. In view of the conditions, it was of interest to note that 7,500,000 tons or 12 per cent. of the whole world tonnage was over 25 years old, and that 4,500,000 tons or 7 per cent. represented ships built in America during the European War which are now laid up, the United States Government having been advised that the greater part of this fleet cannot ever engage in commerce with success. The figures for laid-up vessels must be considered in relationship to these conditions. Ships rust away in idleness quicker than they wear out at sea, and shipowners know to their cost that the sooner obsolete and unprofitable ships are broken up the less is their loss.

Sir Alan expressed disapproval of the action of governments in lending money on easy terms to bring about employment in the shipbuilding centres. This artificial stimulant to the shipbuilding trade was dangerous. Without it the orders for ships would gradually increase, beginning with special types and extending to others, as owners gained the impression that the time of lowest prices was past, but if shipowners, who have had severe lessons of bad trade due to the excess of vessels in the world, got the impression that their business was to be made a cockpit for non-economic government activity, it seemed probable that every ship built before its time by this action would postpone the placing of a dozen or more other orders to a later date than if there had been no interference. Only when the world ceased to quarrel and settled down to trade would the seamen and the ships of the country be fully employed. Every economy in working, every improvement in design, every removal of an unnecessary restriction on trade brought nearer the good time of full employment. Every disturbance of industry and every additional expense thrown on to sea transport, postponed that recovery.

The demand for shipping facilities had greatly diminished through the shrinkage of trade. Industry was burdened with excessive taxation and these conditions must remain until all departments of government service make a real attempt to obtain economy. Extravagant government expenditure at such times, as we are suffering, was fatal to recovery. Even those activities which were easy to justify when trade was good became most pernicious extravagances when trade was reduced to the extent we now experience. Sir Alan cited the case of the government supervision of the mercantile marine, and asked if it was really necessary to spend on that work about four times what it cost in 1913. Such conditions as were indicated by the fact that the Civil Service cost 44,000,000*l.* more in 1923 than in 1913, meant an enormous burden upon industry. The president concluded his able address with a reference to the effects upon Shipping of the disturbed conditions due to the foreign exchange rates and the advantages accruing to the foreign shipowners in cost of running, due to the lag which intervened between the fall in the value of currency during inflation and the slower rise in the price of commodities and wages expressed in that currency. The advantage to the shipowners that inflation provided was the reduction of the capital liability on loans and debentures. Against that must be set the disturbance inflation caused in overseas trade. The dangers of inflation had now been fully exposed, and when they were completely appreciated the gradual return of the nations to economic sanity would follow.

THE CRYSTALLINE STRUCTURE OF ORGANIC SUBSTANCES.

At the Royal Institution on Thursday, February 21, Sir W. H. Bragg, F.R.S., delivered the third of his course of lectures on the above subject.

He commenced by a recapitulation of the principal points of the problem. Until recently he said, the outward form of a crystal was all we had to go by. We could merely measure the angles between its faces, but what we wanted to know was how it came to have this beautiful regularity of form. To this end we had to try to work back to the atoms, and to find out how they were put together to form molecules. There were certain well-marked stages in the study of this problem. We began with the outer form of the crystal. Then the X-rays made possible a great step forward by establishing definitely the space lattice, characteristic of each crystal. This lattice was defined by drawing lines through corresponding points of the structural units, and these lines mapped out in three dimensional space little rhombohedra of definite size and form, which constituted the unit of pattern by the repetition of which the crystal was built up. The molecules formed the component parts of these unit cells, and we had to determine the number in each cell. Finally we came to the atoms. We might regard the molecule, as a company of atoms, which finding that, thus arranged, they would be fairly comfortably disposed, elected to go together and exist as an independent company. Having got these molecules Nature always endeavoured to associate them together more and more symmetrically, and in so doing obtained the unit of pattern, which she repeated again and again in building up the crystal.

In finding out the internal constitution of these, the X-rays helped in different ways. In the first place they gave the size of the lattice without any possibility of mistake or indefiniteness. They next told us certain details as to the arrangement of the molecules in the cell, and this was important, because we might, as shown in the last lecture, have the same kind of symmetry with different distribution of the parts of the molecule, which might be closely grouped together, as in Fig. 6, page 244 *ante*,* or opened out as in Fig. 5. All such displacements of the parts were governed by the law that no displacement could be less than one-half of the distance between the main spacing, since to maintain the symmetry it was necessary that if one of the sheets of molecules were cut in two, and the one part slid forward through a distance equal to the smallest spacing, the two halves of the sheet in question should still be mirror images of each other. This would not be the case if parts of the molecule were displaced to a distance equal to one-quarter of the corresponding side of the unit cell, but was true if the displacement were one-half this distance.

In this connection Professor Bragg then explained in more detail what he meant by stating that a molecule was at the corner of each cell. It meant, he said, that corresponding points or elements of different molecules were thus situated. By selecting one point of any one molecule as the reference point, the relative position of all the other molecules was fixed.

As he had already stated the X-rays determined quite definitely the size and character of the space lattices. The next stages of the problems of crystallography were much more difficult, since although we might know that a molecule was at the corner of each cell, its component parts might be opened out without affecting the symmetry of the crystal. To determine how the molecular components really were disposed we had to get what help we could from chemistry and physics, making use of our knowledge of the sizes of the atoms, and as to whether certain atoms had or had not a tendency to lie against each other. We wanted in short, to find the position of the atoms in the molecule.

In the case of napthalene we had, as explained in the previous lecture, been able to say that each cell contained two napthalene molecules, and we had to find how these two would pack into the cell the

* Erratum.—Through an engraver's error the numbers of Figs. 5 and 6, page 244 *ante*, were interchanged.

dimensions of which were known from the X-ray measurements. We learnt from the chemist that napthalene had two benzene rings of six carbon-atoms each, two of the carbon atoms being common to each ring. The chemist, however, could not tell us the size of these rings. If, however, we assumed that they had the same size as the hexagonal rings shown in the model of the diamond (see Fig. 14, page 245 *ante*), we could try whether the assumption that the benzene ring had these dimensions, would make it possible to fit two napthalene molecules into each unit cell. It turned out that on this assumption the two would just about fit in; with a napthalene molecule at each corner of the cell, shown in Fig. 13, page 245 *ante*. In the next layer the molecules came between these, and it was intended to represent this in Fig. 15, page 245 *ante*, by cross-hatching the two molecules, shown on the right and left, which were not in the same plane as that represented at the centre. This central molecule, as it were, bridged across the other two. The planes of cleavage were also shown in the figure, and across these the crystal broke easily into flakes.

The problem he was trying to solve was how each atom behaved in relation to its neighbours, and to work back as to how Nature made them lie up against each other. The diamond (see Fig. 14, page 245 *ante*) had very, very great symmetry, governed by the single rule that each carbon atom lay at the centre of gravity of four others. This constitution was in full agreement with the conclusions of the chemist who regarded carbon as tetravalent. As shown in Fig. 14, this constitution gave rise to hexagonal rings of atoms, and it might be concluded that the tendency of carbon to form such hexagonal rings was very great. In graphite the arrangement of the atoms was different. The X-rays showed it to consist of parallel sheets, but the investigation was not easy, owing to the difficulty of getting good crystals. One or two good crystals of graphite had, however, now been secured and we might, therefore, hope to solve definitely the problem as to the exact arrangement of the carbon atom in graphite. So far, we knew that the distance between the component sheets was greater than the distance between neighbouring atoms in the diamond, so that the cells of the space lattice were opened out. This, no doubt, was why graphite was so flakey. In the sheets the atoms were apparently in the characteristic rings, and the bond between the atoms in this was one of the firmest known. Hence the lubricating properties of graphite must be attributed to the weakness of the junctions between the sheets. This was easily broken, but owing to the strength of the ring arrangement of the carbon atoms, the sheets, though they slid over each other, held together.

The next question that arose was whether the rings in the sheets were flat or puckered as in the diamond (see Fig. 14, page 245 *ante*). No certain answer could for the present be given, but since the ring itself persisted he was inclined to believe that it retained the puckered form.

The organic chemist had found that the atoms or radicals which could be joined on to the benzene ring did so only at definite points, so that the molecule was framed up like a ship or girder and, like the latter, was an openwork structure, which accounted for the fact that most of these organic compounds had a density of the same order as that of water.

If we could assume that the benzene ring had the same dimensions as the hexagonal rings found in the diamond, we could test this hypothesis by seeing if the molecules, thus constituted, would fit into the cells of the space lattice, the dimensions of which were known. As already stated, the assumption turned out to be justified in the case of napthalene, and it also held with resorcine.

In certain other organic compounds, such as the paraffins and many of the fatty acids, the carbon atoms formed a chain instead of a ring (see Fig. 16). It had lately been found possible to measure the length of these molecules. Their characteristic feature was that the middle or backbone of the chain was made up of carbon atoms, having each two hydrogen atoms attached to it. The ends of the chain were different, as the carbon atoms were attached here either to three hydrogen atoms or to others of equivalent valency. It was found that the length of the chain affected to some extent the properties of the molecule, and was, for example, accountable for the difference between butter and palmitic acid. Their properties, however, depended mainly on the nature of the ends of the chain. If the ends, as in the paraffins, had one carbon atom with three hydrogen attached, they were comparatively "inoffensive" and had no strong attractions. If, however, an end had the constitution represented by — CH = O, this had such a strong affinity for water, that the molecules stood on end when the substance was spread on water. By taking advantage of this fact, Longmuir, Hardy and Adams had made estimates of the lengths of some of these open chain compounds but, as the result of a fortunate observation in the Davy-Faraday laboratory, it was now possible to measure the length of these molecules by the X-rays.

The discovery, in question, was made in some experiments in which a delicate crystal was covered with paraffin for the purpose of protection. On examining the X-ray photographs obtained a

Fig. 16.

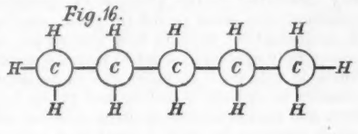


Fig. 17.

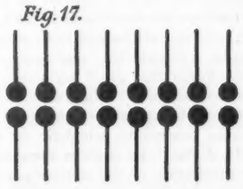


Fig. 18.

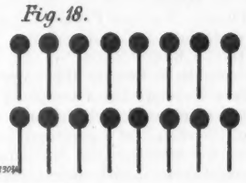


Fig. 19.

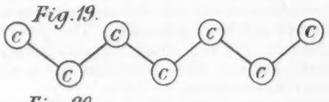
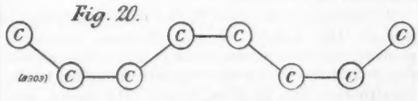


Fig. 20.



number of equally-spaced parallel lines were visible, in addition to those attributable to the reflections from the sheets of molecules in the crystals, and these lines were finally traced to the paraffin. A grease spot was, therefore, a crystal, little as it looked like it. This original experiment led to further inve stigation, the plan followed being to cover a sheet of glass with substances having this carbon chain constitution, and to examine them by the X-ray spectrometer. As the object was slowly turned round a point was reached at which the feeble individual reflections from successive layers of molecules were in phase, and a line was then impressed on the photographic plate. On further rotation, the reflections got out of phase and destroyed each other, but at some later stage, second order reflections were obtained in phase, and a fresh line parallel to the former was impressed on the plate. In this way reflections up to the tenth order were obtained on a single photograph, and by a measurement of the spacing, the distance between the reflecting layers could be deduced. It turned out that in some case the successive layers of molecules were arranged head to head, as indicated in Fig. 17, but in others they were head and tail, as indicated in Fig. 18. The former arrangement occurred when the ends of the chains had a strong attraction for similar ends, whilst the head to tail arrangement was obtained when the ends consisted of one carbon atom attached to three hydrogen ones. Some of the chains measured were found to have as many as twenty-one links.

The structural formulas of the chemist represented all the carbon atoms as lying along a straight line (see Fig. 16) but, as already stated, in the diamond, each carbon atom lay at the centre of gravity of four others. The bonds or links of each individual atom were, therefore, in no case diametrically opposite to each other, as would be the case if the structural formula of the chemist represented physical reality. All the four bonds made equal angles with each other (about 106°-46′), and the measurements made showed that this feature was retained in the open chain compounds. In some of these the carbon atoms were arranged as indicated in Fig. 19, whilst in other cases the arrangement was as in Fig. 20. The only further arrangement of carbon atoms consistent with maintaining the constancy of the angle between the bonds would be a "corkscrew arrangement." This was met with in the case of certain silicon compounds like quartz, but so far was not known to occur with carbon, save in the modified way exemplified by Tartaric acid.

In Iceland spar, however, X-ray analysis showed that each carbon atom was situated at the centre of an equilateral triangle, the corners of which were occupied by oxygen atoms. In this case it appeared that the oxygen atoms had grabbed from the carbon atom the whole of its four valency electrons, leaving it positively electrified. In order to make up the ring of eight outer electrons, which the oxygen atom liked to have, each needed to capture two, or six in all. Of this total, four were obtained from the carbon and the remaining two were given up by the calcium. This done, the three now negatively electrified oxygen atoms were attracted round the positively-charged residue of the carbon atom.

NOTES.

The British Corporation.

At the annual meeting of the British Corporation for the Survey and Registry of Shipping, which was held on Wednesday, February 20, in Glasgow, Mr. George Sloan, who presided, spoke of the prevailing depression in the shipbuilding industry as due to the existence of more ships than there was work for under the existing trade conditions. He, however, saw some hope for the immediate future in that there was need for the small classes of ships, which made up half the world's tonnage, but which had been out of production for the last ten years. Again, it was well known that no matter what was the condition of trade, whenever improvements were made in design or by use of new types of machinery resulting in marked gains in costs and in economy of running, there followed new building. The work of the British Corporation was always more regular in quantity than the total volume of the world's shipbuilding. During 1923 the new-classed tonnage was 204,000 tons, or little less than the figure for 1922, although the total output of ships for the world was only two-thirds of that of the previous year. The total classification by the British Corporation amounted to 320,000 tons in 1923, of which 56,000 tons was also classed with the Registro Italiano, 46,000 with the Imperial Japanese Corporation and 13,000 with the American Bureau, its allied organisations. A small but fairly regular stream of new contracts had been placed since the termination of the long period of lockout in the yards. Work on order, which was intended to receive classification, amounted to 350,000 tons compared with 407,000 tons at the same time last year. With a return to industrial peace improved figures would probably be shown, and intervals of many years between the placing and completion of the contracts would cease to be the normal experience.

The Failure of the Gleno Dam, North Italy.

As announced in the daily press at the time vast destruction was wrought by the collapse on December 1 last of the Gleno dam, erected on the Dezzo River some 30 miles north-east of Bergamo, North Italy. In places the flood wave reached 100 ft. in height, 500 lives were lost, and property was destroyed to the value of 150,000,000 lire. Some particulars of the structure and of the causes which occasioned the catastrophe are given in the

Engineering News-Record, of January 31 last, as the result of an inquiry conducted by Mr. A. de Martini, an engineer of Genoa, assisted by Mr. A. C. Janni of New York. From our contemporary's article it would appear that from the purely technical standpoint the disaster serves to emphasise the dangerous character of badly made reinforced concrete. This material demands the most conscientious care in design, in the selection of material, and in the execution of the work. When this has been lacking, there have been quite a number of very serious failures. The Gleno dam was a reinforced concrete structure of the multiple arch type, which rested on a gravity base of masonry. It was 143 ft. high above stream level and retained 190,000,000 cubic ft. of water. In plan it comprised a central curved section of 9 semi-circular arches, each of about 26 ft. 3 in. span, flanked by straight end sections of which one comprised 12 arches and the other 4. The arches had axes inclined at 53 deg. to the horizontal. Of the nine arches over the central section eight failed, as well as an adjacent arch on one of the straight sections. The masonry base largely remained in place. According to the report given in our contemporary the masonry of the gravity base was built in lime mortar although the specification called for cement. The gravel used as aggregate was unwashed and the concrete was porous. It was mixed by hand and was not rammed into the forms. The reinforcement was scrap netting which had been used during the war for protection against hand grenades. The original plan called for a gravity dam, but the concessionaires subsequently sought authority to replace this by the multiple arch type. Permission for the change was not granted, but the work was proceeded with in spite of government orders to stop construction till the plans had been approved.

LITERATURE.

The Gyroscope: Its Practical Construction and Application. By P. P. Schilovsky, President of the Gyroscopic Society of Petrograd. With a Preface by Professor C. V. Boys. F.R.S. London: E. and F. N. Spon, Limited. [Price 14*s.* net.]

It was a complaint of the late Professor Perry, and doubtless of many others, that useful discoveries have been delayed and beneficial mechanical inventions lost from the want of educated observation of ordinary phenomena. The familiar cannot awaken enthusiasm, and the dynamical properties exhibited are accepted without enquiry. The top, so instructive by its motion, fails to arouse any curiosity, and the lessons it can so well teach are disregarded. Tops have been spun for thousands of years without suggesting that the explanation of their behaviour could lead to the construction of mechanism that would have important engineering results, and when adequate explanation was forthcoming, it was not always in a form that was "understanded of the people," but was supposed to have no further value than to illustrate such useless problems as the precession of the Equinoxes, with which no sane person would trouble himself. If some more venturesome than others saw the possibilities of useful application, partial or imperfect knowledge would not infrequently lead to failure, more or less complete, and bring science into ridicule or disrepute.

M. Schilovsky is of opinion that the lack of knowledge of the mechanics of the gyroscope has contributed to the slowness of the progress made with the practical application of its principles, and he urges that if our engineers were better instructed in the dynamics of rotating bodies, we should have long since perfected the three systems of gyroscopic steady locomotion, and we should be in possession of stable monorails, stable ships, and stable aeroplanes. He entertains the confident hope that gyroscopes, skilfully and intelligently applied, will finally reduce the steering of aeroplanes to the simplicity of driving a car. Whether this hopeful outlook is justified may be doubted, but his suggestion that practical gyroscopic apparatus should be at the disposal of engineering classes is sound. Diagrams and equations do not appeal equally to all, but a working model conveys its lesson swiftly and surely. As a desirable accessory, the author would add a rotating platform, driven at slow speed, to illustrate the effects of curves. This may be a luxurious detail, but one we imagine that would not meet with the approval of Professor Boys, who, in an introductory preface, while admiring the author's enthusiasm and ingenuity, maintains that the greater intricacies of the gyroscope are rarely of importance to the inventor. Engineers, it is urged, are interested mainly in the steady sideways movements, and "the relations between these, the form, weight and speed of rotation of the fly-wheel and the forces applied to the axes of the fly-wheel and their distance apart, are of the simplest, easily learnt and expressed by the shortest equation."

The inference may perhaps be fairly drawn that the physics of the subject needs to be presented in various ways, in order to gain the attention of the variously equipped and endowed, and the author has endeavoured, boldly, if not successfully, to cater for all classes of students. He himself is mainly interested in the problem of mechanical stabilisation, and seeks to inform those who have little mathematical training how gyroscopes may be successfully applied in order to increase stability in unstable vehicles. To enlist the enthusiasm of his readers, he appeals to history, and points to the failures and partial success of many schemes, while for their guidance he gives a number of rules and corollaries, which are no doubt correct but are difficult to follow, as is every attempt to express mathematical formulæ without the assistance of symbols, notwithstanding that great assistance may be given by well-constructed diagrams. Conscious that this method of expression may prove inconvenient to those possessing scientific or technical knowledge, Mr. J. E. S. Ross gives some additional notes on the mechanics of the gyroscope, intended for those who are familiar with the ordinary laws of dynamics. Finally, Professor Papkovitch addresses the trained mathematician and scientist, but unfortunately thorough discussion by this eminent authority is considered outside the scope of this work. We have therefore but a sample of the distinguished Professor's work, which deals with the explanation of the change of a gyroscope's eccentricity on curves, the mathematical discussion of the author's monorail system, with some investigations of the relations of the size of the gyroscope to the car in small and large monorails. This programme is ambitious, but not altogether satisfactory. It necessarily leads to much repetition and a want of order and thoroughness.

M. Schilvosky sketches in the most sympathetic manner the history of the Brennan monorail, pointing out the good and weak points in the original design and the later improvements embodied in the construction due to Herr Schirl. He shows, too, what was effected by Schlick, by Swan, Hunter, Richardson, and others, in the attempts to stabilise ships and aeroplanes, before entering on his own plans. The mechanical principle employed in all cases, based on a satisfactory theory, was naturally sound, but the practical difficulties of construction were not effectually overcome. Brennan's car advanced as far as any towards success, but the gyroscope placed inside the car failed to preserve its own equilibrium, and the car, once in motion, soon began to oscillate, or to "precess," causing the car to sway from side to side till it overturned. Subsequent efforts have been mainly directed to the provision of mechanism to correct this tendency to "precess." Brennan adopted the plan of arranging the gyroscopes, rotating in opposite directions. Schirl simplified the construction by making the oscillations of gyroscope and car isochronous, whence they might be damped by accelerating the precession. The author, mistrusting either plan, adopted unstably suspended oscillating gyroscopes, with variable eccentricity. The tendency to precess is overcome by the automatic engagement of toothed racks and pinions, which disengage as soon as the car has regained its normal position. The automatic device is not fully explained, for the necessary patents have not yet been granted, but Mr. C. V. Boys speaks of the maintenance of gyroscopic stability having been accomplished with all the author's customary ingenuity.

Apparently, though not distinctly stated, several collaborators have assisted in the preparation of this treatise, or M. Schilovsky has supplied a summary of original work prepared by others, with the view of presenting a clear idea of what is involved in the production of a complete monorail system. Mr. Kinder shows how rolling-stock and small passenger cars may be conveniently designed, and Professor Godlitzky-Svirko supplies notes on the construction of the permanent way. Similarly, Mr. R. N. Wulf works out the details of giant cars, providing accommodation for 400 passengers and furnished with a gyroscope, 8 ft. in diameter and weighing 30 tons, revolving 1,500 times per minute. The speed of the giant car of the future will travel at a rate exceeding 90 miles an hour, the motor power being supplied by electricity at 3,000 volts fed through a second rail, the track rail serving as return current wire. The energy required to propel the car, weighing 340 tons, and to work the gyroscope is worked out in greater detail by Mr. R. A. Luther, who proposes to employ 400 r.p.m. Diesel motors, coupled direct to double-armature generators as used on submarines. As an exercise the details are interesting, but the scheme, if carried to a practical issue, will probably proceed on more modest lines, till experience is acquired and confidence established. Finally, Professor Evreinoff, taking time by the forelock, examines the financial aspect of the problem, and presents a balance-sheet showing the pecuniary gain to be derived from adopting a monorail system. The result is very favourable, but unfortunately the items are built on forecasts rather than on facts, and the conclusion seems too inviting.

The underlying problem is, however, will the scheme of a monorail, carrying vehicles stabilized by gyroscopic action, work to the safety of the public and the satisfaction of shareholders? We confess that we view with some trepidation the prospect of installing on a train 30 tons of iron, whirling with enormous velocity, but others with greater knowledge and experience may be more easily assured. In any case, the author deserves our thanks for breathing new life into this topic and compelling us to reconsider the merits and the risks of the monorail.

The Mechanical Properties of Fluids. A collective work. By C. V. Drysdale, Allan Ferguson, A. E. Geddes, A. H. Gibson, F. R. W. Hunt, Horace Lamb, A. G. M. Michell, and G. I. Taylor. Blackie and Son, Limited. London. [Price 20*s.* net.]

In this extremely useful book of reference the mechanical properties of fluids are discussed and described by men, each of whom is an acknowledged adept in the branch with which he deals. Some of them have, moreover, been responsible for certain of the more important advances made during the past few years. The opening chapter is contributed by Dr. Allan Ferguson, who has chosen for his subject the characteristic differences between liquids and gases. The inquiry is approached from the historical standpoint, which is that naturally presenting itself to the student, although, in most cases, the actual path hewn by the pioneer can be very materially bettered. In such cases, at any rate, it is the good which men do that lives after them. The divagations of the original investigator into blind alleys and false theories are soon forgotten, when they have at length succeeded in discovering the true line of advance. Dr. Ferguson reproduces Boyle's original account of how he determined the isothermal compressibility of air. This leads naturally to certain equations of state, but these are more fully discussed later on in the same section. In dealing with surface tension, Dr. Ferguson draws attention to the error involved in the common practice of equating surface tension to surface energy. If our memory serves, Maxwell himself went wrong here. At the best, the two are only numerically equal, but even were this universally the case the difference in the dimensions of the two quantities is apt to prove very puzzling to the student. Actually, however, since surface tension varies with temperature, it is not even numerically equal to the surface energy, a correction being required analogous to that which Helmholtz introduced into Thomson's calculation of the E.M.F. of a galvanic cell. An interesting part of this section of the volume is that showing how simply the form of Stokes law for the terminal velocities of small spheres can be derived from purely dimensional reasoning. An

interesting application of this law is the determination of the viscosity of very viscous fluids by measuring the terminal velocity of small bicycle balls falling through them. The author gives, without demonstration, the partial differential equations for the viscous flow of a fluid, but the proof is given later in the purely mathematical section of the volume. Equations of state are subsequently more fully discussed, and Joule's formula connecting the pressure of a gas with the average translational kinetic energy of the molecules is simply and clearly derived. A useful appendix shows how readily the transformation of Laplace's equation from rectangular to polar co-ordinates can be effected by taking advantage of physical considerations. By the purely mathematical methods the transformation is a somewhat laborious one.

The section on hydrodynamics is contributed by Professor Horace Lamb, F.R.S., who is well known as the author of the authoritative treatise on this subject. In the present case, Professor Lamb makes no inordinate demand on the mathematical acquirements of his readers, most of whom should find little difficulty in following the argument. Included in this chapter is a note on the rate at which vorticity is diffused, a matter which is becoming of considerable importance in connection both with aerodynamics and meteorology.

For the next section of the book, Mr. A. G. M. Michell is responsible. In the main, this deals with the mathematical theory of lubrication which was originated by Osborne Reynolds, whose clumsy mathematics was subsequently improved by Sommerfeld, without, however, any extension of the theory to intrinsically new problems. This latter feat was accomplished by Mr. Michell, with the well-known important practical results; and subsequent writers have shown that Osborne Reynolds' theory also holds good when lubricated surfaces roll over each other instead of sliding. Referring to Sommerfeld's treatment of the semi-circular brass, Mr. Michell points out that the solution given involves the existence of negative pressures over certain arcs, and as under ordinary conditions such negative pressures are impossible, the solution found can seldom correspond to reality. Mr. Michell draws attention to one very interesting point, viz., that since it is the reduction of the viscosity of the lubricant with rise of temperature which makes it possible to get quite fair lubrication with centrally pivoted blocks, such blocks will be unsatisfactory with lubricants such as air, in which the viscosity increases as the temperature rises. Moreover, whilst with ordinary lubricants pivoted blocks can be run in the wrong direction (subject to somewhat high frictional losses) it has been found impossible to do this when carbon bisulphide is used as the lubricant, since the viscosity of this fluid varies but slowly with changes of temperature.

Professor A. H. Gibson is the author of the next section of the volume. He treats of the turbulent flow of fluids in pipes, and of hydrodynamic resistances generally. A very useful and valuable section is devoted to the discussion of dimensional homogeneity and dynamic similarity. This is a subject of which the importance is still far from adequately recognised, even in places where they teach. It is still quite common to find empirical formulas, dimensionally impossible, put forward to represent experimental data. The result is that such formulas are applicable only to the particular series of experiments from which they were derived. We may perhaps be permitted one small criticism in this connection. We do not think that it is made sufficiently clear that, in general, dimensional reasoning gives merely the form of successive terms in a power series. Thus the author follows Reynolds in writing

$$\frac{\partial p}{\partial x} = \frac{\nu^{2-n}}{d^{3-n}} v_m^n \frac{B^n}{A}$$

whereas the complete expression should be

$$\frac{\partial p}{\partial x} = \Sigma \frac{\nu^{2-n}}{d^{3-n}} \cdot v_m^n \frac{B^n}{A}$$

It has, in fact, been far too commonly assumed that the series on the right of the above equation can be represented by a single term, and it is very important that the student should be impressed with the fact that this is not generally the case. Professor Gibson is also responsible for the chapter dealing with water hammer and allied phenomena. The application of observations on soap films to the determination of torsional stresses in bars of irregular area is described by Mr. G. I. Taylor, F.R.S. The method formed the subject of a paper written in conjunction with Dr. Griffiths which he presented to the Institution of Mechanical Engineers in 1917. It originated with Prandtl. One interesting diagram given in this chapter illustrates the concentration of stress round a key-way cut in a shaft. Fortunately, our materials of construction generally refuse to behave as homogeneous elastic solids, and conditions are seldom so serious as calculation would indicate. Were this not the case, it would have proved impracticable for man to have developed structures and machines, and, perhaps, it might even have proved impossible for him to have evolved his own body.

A highly interesting section on submarine signalling is contributed by Dr. C. V. Drysdale, and Mr. F. R. Hunt has a valuable contribution on the reaction of air to artillery projectiles. He reproduces a singularly fine photograph showing the waves of compression formed round a high velocity rifle bullet. The photograph also shows very beautifully the turbulence left in the wake of the projectile.

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE Annual General Meeting of the Institution of Mechanical Engineers was held on Friday last, the 22nd inst., the chair being occupied for the first part of the proceedings by Sir John Dewrance.

THE ANNUAL REPORT.

The minutes of the previous meeting having been read, the annual report for 1923, which was taken as read, was adopted without discussion. Of this report we give the following summary:—

The seventy-seventh annual report showed a net increase on the roll of the Institution of 493 names, the total amounting at the close of 1923 to 9,227. The additions numbered 886 including 136 members, 236 associate members, 135 graduates and 351 students. The total number of names coming under the heading of deductions was 393, of which 114 were transfers, the remainder representing deaths, resignations, &c. There was a net increase in each class, the largest figures being 306 in the case of students, 89 in the case of graduates and 63 in the class of associate members. Among the losses by death the following names may be quoted:—Mr. Mark Robinson, Member of Council and Vice-President; Mr. H. A. Ivatt, Member of Council and Vice-President; Mr. Robert Matthews, former Member of Council, Sir G. Green, a Member since 1861; Mr. H. L. Wallis, a member since 1868; Mr. Gustave Eiffel, Hon. Life Member. The accounts for the year showed a balance of 1,037*l.* of revenue over expenditure, compared with a small deficit in the previous year. For the year under review the revenue was 31,185*l.*, and the expenditure 30,148*l.* In connection with research, work for the Alloys Committee had been done in the way of providing furnaces and apparatus. With regard to cutting tools, work on the strains in planing in the work in front of the tool had been done by Professor E. G. Coker; Dr. T. E. Stanton had worked on the abrasive force of the chip on the tool face, and Dr. W. Rosenhain on the deformation of the metal around the tool. The work of the Hardness Test Committee had continued at the National Physical Laboratory. Shore tests on Beardmore-Tosi, Scott-Still and Werkspoor engines had been carried out in connection with the Marine Engine Trials Committee. A special committee, on which the Institution was represented, had been appointed by the Institution of Civil Engineers on Heat Engines and Boiler Trials. A third report of the Steam Nozzles Committee was in process of compilation. Work had continued under the Wire Ropes Research Committee.

Five local branches of the Institution were in existence, and had held a number of meetings, &c. The three graduates sections had also had full programmes. The Engineering Joint Council had been regularly instituted. During the year the sum of 1,000*l.* had been presented by Mr. W. H. Allen to enable a graduate to take an Honours Course at Cambridge. Mr. R. P. Jones had enabled a second graduate to take a similar course.

The Thomas Hawksley Medal had been presented to Professor A. H. Gibson and a premium to Mr. H. Wright Baker for the paper on Exhaust Valve and Cylinder Head Temperatures in high-speed Petrol Engines. A Thomas Hawksley premium had also been presented to Mr. H. C. Young for his paper on Some Mechanical Problems of the Rubber Industry. T. Bernard Hall prizes had been awarded to Mr. Dempster Smith, Mr. W. J. Walker, Professor F. W. Burstall, Mr. H. Wood and Mr. W. J. Kearton, for papers contributed during 1922 and 1923. The Thomas Hawksley lecture had been delivered by Sir Westcott S. Abell. In connection with the examinations prizes had been awarded to Messrs. J. A. Henson and George Parker. Prizes had also been awarded for papers by the following Graduates:—Messrs. F. Dollin, R. C. Bond, H. W. Hollands, H. R Hockley and K. C. Banell. The National Certificates and Diploma Scheme now included 87 schools.

ELECTION OF OFFICERS.

After the presentation of prizes the Secretary announced the result of the ballot in connection with the election of officers. This was as follows:—President, Mr. W. H. Patchell; Vice-Presidents, Mr. D. Adamson, Mr. R. W. Allen and Mr. W. Reavell; Members of Council, Engineer Vice-Admiral Sir G. Goodwin, Mr. H. N. Gresley, Mr. R. Maunsell, Mr. W. Taylor, Sir J. E. Thornycroft and Mr. R. Williamson. The following Past Presidents had also been appointed to serve on the council: Sir J. A. F. Aspinall, Sir J. Dewrance, Dr. H. S. Hele-Shaw and Capt. H. Riall Sankey. Mr. W. H. Allen and Sir R. Hadfield, past vice-Presidents, had also been appointed. The council had in addition co-opted the chairmen of the local branches as follows:—Midland Branch: Major Thompson; North Western Branch: Mr. A. Saxon; Yorkshire Branch: Professor Charnock; Glasgow and West of Scotland Branch: Professor A. L. Mellanby; South Wales Branch: Mr. J. W. Burr.

INDUCTION OF THE NEW PRESIDENT.

On Sir John Dewrance vacating the chair in favour of the new President (Mr. W. H. Patchell), Capt. H. Riall Sankey proposed a vote of thanks to the retiring president. During the year of Sir John's tenure of office, Capt. Sankey recalled the extension of the National Certificates to Scotland and the extension of the Institution's work of research on alloys. Dr. H. S. Hele-Shaw supported the proposed vote in felicitous terms, and, it having been put to the meeting and passed by acclamation, Sir John Dewrance, in acknowledgment, observed that he had felt some satisfaction in having been able to bring together the Royal Society, the Institution of Civil Engineers, the Institution of Electrical Engineers, the Institution of Naval Architects and the Institute of Mining and Metallurgy, for the purpose of investigating the true properties of alloys of iron. It was to be expected that there would be great improvement as a result of this joint investigation. Dr. Rosenhain had stated that the assumption was warranted that if only an amorphous alloy of iron could be obtained, such a material would stand a pressure of 4,000 tons to the square inch, and would do that at a temperature far beyond that applicable to any known steel at the present time. Even if only part of these effects could be secured the world would be greatly benefitted.

REPAIR AND UPKEEP OF PNEUMATIC TOOLS.

The remainder of the meeting was devoted to the discussion on Mr. R. W. Wilson's paper on the "Repair and Upkeep of Pneumatic Tools," adjourned from the 8th inst. Before, however, the discussion was resumed Mr. Wilson corrected a number of mistakes which had appeared in the paper. These related to the costs given in the table in the paper. They were of the order of one per cent. and under. The figures given as "6*s.* $\frac{2}{3}$*d.*" in column 3, page 219 *ante*, for the cost of labour should have been reproduced as "6$\frac{2}{3}$*d.*"

Mr. J. L. Hodgson stated that the problem of accurately metering the air used by a pneumatic tool was by no means an easy one. Practically all such tools caused pulsations in the air flow to be metered, and any meter whose action depended upon the loss of pressure across an orifice would read fast; since if the pointer or its equivalent were damped so as to give a steady reading, it would show the mean of the pressure differences instead of the mean of the square roots of the pressure differences, which latter it was necessary to obtain if an accurate measurement of the flow was required. Fig. 1, page 278, shows an arrangement consisting of a supply of compressed air (supposed to be non-pulsating), a measuring orifice O, a throttle valve T, a receiver R of capacity C, and a pneumatic tool or other source of pulsation. Fig. 2 shows various wave forms at the measuring point O, and the percentage error of the meter for each of these wave forms. Assuming that the square wave form represented by the thick black line existed at the metering point O, when there was no throttling at T and no receiver capacity at R.

it would be seen from the diagram that the calculated meter error was approximately 40 per cent. By increasing the capacity C or the throttling at T, the various smoother wave forms shown in Fig. 2, could be obtained with corresponding diminutions in the meter error.

The extent of the meter error depended upon the value of the factor CFL/ZQ, where C was the capacity (in cubic feet) of the pipe line between the pneumatic tool and the measuring orifice; F was the frequency (number of pulsations per minute) with which the

Fig. 1.

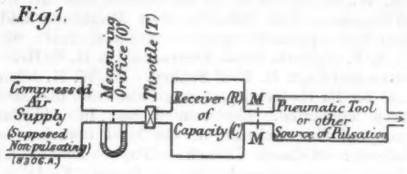


Fig. 2.

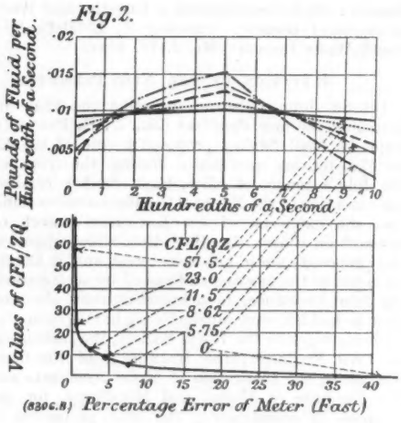
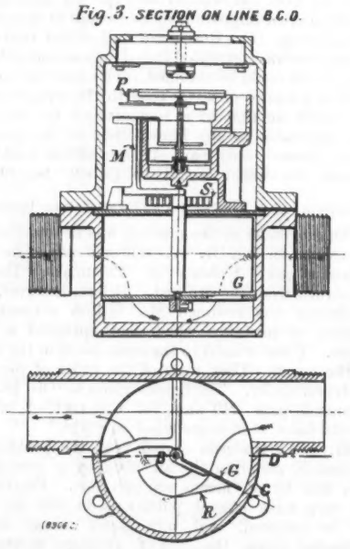


Fig. 3. SECTION ON LINE B C O.



wave form repeated itself; and L was the loss of pressure (in lb. per square inch) across the orifice O, at the mean flow Q; Z was the product of the specific volume (cubic feet per pound) of the fluid at the pressure and temperature which existed in the receiver of capacity C, and its absolute pressure (lb. per square inch); Q was the quantity of fluid passing (lb. per second). Thus even if the meter were accurately rated for a particular condition which gave, say, a 20 per cent. error, any slight variation in the frequency, or the wave form, or the quantity passing, would alter the error by a considerable percentage. The error was very sensitive to the exact wave form of the flow, and the only safe thing to do, therefore, was to increase the receiver capacity and the throttling to such an extent that the meter error was of the order of 2 per cent. or 3 per cent. Any change in the other factors upon which the error depended would then not cause a large percentage error in the quantity of air measured, since the total error would always be under 2 or 3 per cent. This was clearly shown by the curve in Fig. 2. The theoretical proof of the CFL/ZQ relation was given in the Transactions of the Institution of Naval Architects, vol. lxiv, page 192.

It was often inconvenient or impossible in underground work to provide a receiver of sufficient capacity to enable the air consumption of, say, a coal cutter to be measured with accuracy. To enable this to be done, the speaker and one of his assistants, Mr. F. Gray, had evolved the meter shown in Fig. 3. The meter consisted of a light gate moving in a circular cavity and opening up a port in the bottom of the cavity as it moved. The motion of the gate was resisted by a spiral spring, and the shape of the port was such that the angular movement of the gate from its zero position was proportional to the flow passing. If, therefore, the gate was made sufficiently light to enable it to follow every variation in the flow, the true mean flow could be obtained by ascertaining the mean position of the gate. This was done by damping the motion of the pointer P by means of an oil dashpot, and connecting an arm M attached to the gate to the pointer spindle by means of a hair spring S. Owing to the difficulty of making the gate of sufficiently light material, the meter was only accurate for pulsations of less than, say, 300 per minute. Above this value the gate could not follow the pulsations with reasonable accuracy, and the meter tended to read fast unless a receiver and a throttling device were placed between it and the source of pulsation.

There were two other meters on the market for measuring the air supplied to pneumatic tools. One of these, which was supplied by Messrs. Mavor and Coulson was illustrated diagrammatically in Fig. 4. Here a plug valve, to which a dial was attached, was shut down until it was sufficiently closed to cause the weighted piston to rise. The actual quantity

Fig. 4.

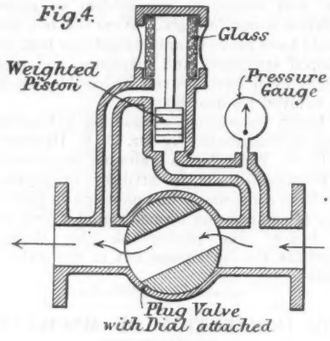
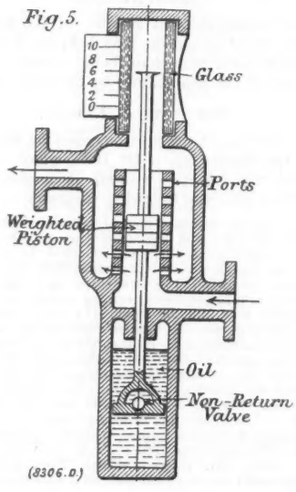
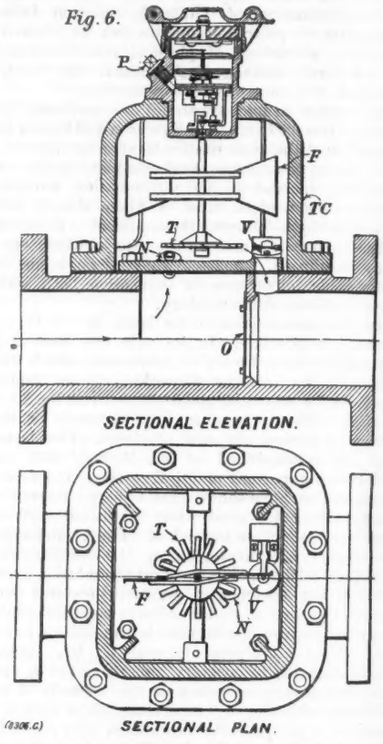


Fig. 5.



of air passing could then be obtained from the reading of the dial attached to the plug valve and the temperature and pressure of the air at the metering point. If used on pulsating flows, a receiver and some throttling should be interposed between the meter and the source of pulsation if accurate results were to be obtained. The other meter was illustrated in Fig. 5. It consisted of a piston working in a cylinder whose walls were drilled with a number of equally spaced ports. In order to prevent the hunting of the piston a dashpot

Fig. 6.



was provided, and as the meter was naturally found to read fast when used for measuring pulsating flows, a non-return valve had been provided in the dashpot piston in order to allow the piston to descend more readily than it ascended.

The accuracy of a meter under pulsating flow conditions could be easily checked by putting the meter at the point marked MM on Fig. 1, and increasing the capacity of the receiver R and the throttling at T until, with a given flow through the meter, there was no further change in the indication of the manometer at O with any increase of capacity or throttling. The manometer at O was then reading correctly. If the registrations of the meter M still agreed with those of the meter at O, after due allowance had been made for any difference in the pressure and temperature of the air at the two meters, they could be considered reliable. If they differed, their difference was the error of the meter at M.

Mr. Hodgson then referred to the meter shown in Fig. 6, which had been designed to measure the air supplied to groups of pneumatic tools. This meter was of the rotary type registering directly on a counter. An orifice was provided in the pipe line and there were two nozzles on a shunt circuit, driving a turbine whose speed was kept down by a fan. The counter gearing was continually bathed in oil (oil could be inserted through the plug P when the meter was under pressure). The oil from the counter box passed through the top bearing of the rotor and through the hollow shaft which carried it, and so lubricated the bottom bearing. The wear on the parts was immensely reduced by the damping fan F which kept the maximum speed of the rotor low. A great part of the weight was taken off the bottom pivot by the impact of the jets through the nozzles N. This further reduced the wear. Any grit or other extraneous material in the pipe line passed

straight through the orifice O, and the turbine chamber TC was found to be clean even after months of running. The turbine T was completely protected from overload by means of the valve V which shut down and closed the shunt circuit when the overload reached about 40 per cent., and opened up again when the overload fell to about 10 per cent. The meter thus always registered its rated maximum flow and was accurate down to one-tenth of the maximum flow.

By using meters of this type it had been possible to detect and keep a check on leakages to such an extent as to save 50 tons of coal a week at one colliery, and to shut down a 4,000 cub. ft. compressor at another, and so on. In this latter case, assuming a power cost of a penny per unit, the shutting down of the compressor meant a saving of approximately 2*l.* an hour. Mr. Hodgson said it was very desirable that simple and reliable standard methods of air measurement which any user of compressed air could appeal to, should be adopted.

Mr. W. G. Corner referred to the table of details, suggesting that there appeared to be an inaccuracy in the column headed "Cost of one for twelve months," from which it would seem that 79 machines cost, for twelve months, 659*l.* 4*s.* 9½*d.* That would represent considerably more than 2*l.* 13*s.* 7*d.*, the cost of one machine for twelve months.

Mr. Wilson, in reply to this, pointed out that the number of repairs totalled 246 in twelve months, and the total cost should, therefore, be divided by 246 to arrive at the cost of one repair for the twelve months.

Mr. H. Bing, who followed, doubted if many firms kept account of costs in such detail that they could state the cost of repairs for each tool; it would be considered too expensive to do so. He thought, however, that the value of the repair and upkeep information given in the author's table would be increased if more particulars could be given of the tools mentioned; for example, the rating of the various machines and the different sizes, and in the case of drills the maximum drilling capacity, while in the case of hammers it would be useful to know the maximum size of rivet worked. The author might also, with advantage, have furnished particulars of the construction of the pneumatic tools, particularly the drilling machine. The arrangement of the four cylinders in connection with these tools was becoming general, but the different makers introduced considerable differences in regard to valves, &c. There was also difference in the construction of hammers. It would also be helpful in deciding upon the value of the figures in the table if some indication were given of whether the machines were in daily or occasional use. Had the author arrived at any conclusion as to when a pneumatic tool should be replaced by a new one instead of being repaired. He believed that in America the practice was to renew these tools yearly when they were in constant and regular use. This practice did not obtain here. He thought hammer tests on cold convex and concave test pieces could not be compared with actual work as the conditions were so different. As to the length of rivets, he thought that rivets should be, if anything, on the long side.

Mr. Simmons also referred to the author's table of costs, in which the ratio of time to material varied very considerably. In some cases the time exceeded the material by quite a large amount. That, he thought, brought out the great importance of simplicity in a hammer, and the ability to dismantle and reassemble quickly. This question was not always looked into carefully enough. He had heard many repair men liken certain tools to jig-saw puzzles, and drills offended in that respect more than hammers. Some rivet hammers offended in having dowels, and others required special tools for assembling. Dowels and screw plugs should be reduced to the minimum. Not long ago he had had occasion to dismantle a French hammer. The valve box was recessed into the handle and dowelled on to the cylinder to keep it in place. On removing the handle, the valve box refused to come out, and it had taken nearly half-an-hour to get it out. The cause was a loose plug backing on the hole and jamming inside the threads of the handle.

Leakage in permanent pipe-lines was inexcusable, but temporary lines did not receive the same care. In temporary contract work the pipe-lines usually leaked very badly, and were nearly always too small. A mixture of graphite and grease on the screw couplings made the lines absolutely tight, and they came apart again as good as new afterwards, ready for the next job. A friend of his, after a contract, had pipe-lines taken apart in sections, and put boys on to hammer each section to get out the scale; boiling oil was then poured through them and they were put in the store, with the result that it was known that for the next job the pipe would be free from dirt. Strainers were important, especially in contract work, in which the conditions were not good. The air was never as clean as it was in a shop job. The compressor was often stood where there was a lot of dust. Personally, he preferred a strainer in the hammer itself—a large area strainer which could be easily removed when the hammer underwent periodical overhauls. If the strainer was worn through dust going through with the air it was then exchanged for a new one. Strainer adaptors added bulk to the hammer and blocked up very quickly. He thought the diagram comparing the results of the British and foreign hammers should be qualified by information as to the bore, stroke, the number of blows and the air consumption; otherwise they were a little confusing. He agreed fully with the advisability of high pressure as a rule; but the increased power was not fully represented by the 10 per cent. mentioned as the difference in power required to compress to 100 lb. as compared with 80 lb. An increase of from 13 per cent. to 15 per cent. occurred in air consumption, depending upon the hammer.

Mr. R. C. MacDonald advocated the long rivet, and could not see what mistake could be introduced by having them long. The purpose of the rivet was to fill the hole, and the more material was put into the hole the better would be the riveting. The chief difficulty arose in connection with the heating of the rivet. It should be heated right up to the neck, that being the most difficult part to fill. Long rivets especially should be well heated. He had known rivets 1 in. in diam. and 11 in. long closed by the pneumatic riveting hammer. If such rivets were not well heated at the neck they would never fill the holes.

Mr. Frank Hills, in referring to certain diagrams relating to crushing test with various hammers, stated that he had replotted these since the previous meeting, and in their new form they showed the same type of curve as given in the figures in the paper.

Mr. H. J. Brackenbury said the author's table suggested that if a man had, say, his watch repaired five times in a year he had five watches; he thought the basis should have been the number of tools repaired and not the number of times that the tools were repaired. With regard to trouble from water coming down pipes where there were overhead lines, it was now usual to bring out the branch pipes from the top of the line and not from the bottom. Being interested in finding out precisely what horse-power these machines would yield, he had got a man of the senior wrangler type to make a thorough investigation. The result was startling, the efficiency exceeding by 50 per cent. the maximum theoretical value! A good check could be obtained as to losses by noting at the meal hour the time taken for the pressure to run down. If the pressure ran down very rapidly a leak, obviously, had occurred.

Mr. S. T. Williams mentioned, as a probable field for development, aircraft riveting, where innumerable rivets were required for the spars, ribs, &c., of wings. Rivets of $\frac{1}{16}$-in. to $\frac{1}{8}$-in. in diameter were needed in tens of thousands, and with rivets of these dimensions length was an important factor, as serious trouble might arise if the rivets were too long; the rivet would topple over. A method of examining the efficiency of a rivet was to photograph a longitudinal section to about six diameters magnification. In the case of steel aeroplanes, manufacturers were committed to riveting; they could not flirt with welding. It was, therefore, up to the makers of pneumatic tools to design a reliable riveter by which the machine could be turned out on an economic basis.

Mr. R. W. Wilson in replying to the discussion agreed that it was most important for every user of pneumatic tools to have efficient air meters. A standard meter was desirable. When tackled on consumption, manufacturers usually pointed to the absence of a standard meter. In connection with the table, the difficulty was that the 79 effective tools in the store were not in use every day; only a selection of them was so used. It would be unfair to compare a tool used every day with one used occasionally. A tool that, for some reason, was only used occasionally—perhaps the riveters might not like it—would then naturally show up best in respect to repair cost. He felt, therefore, that the fair way was to take the number of repairs that each tool had undergone and divide the total cost by the number of repairs. Other things being equal, the tool that did the most work was repaired the most often. He had been asked for particulars of construction of the tools, but to go into that would take too long, the variety of the different types being so great. A long rivet was a good fault if the rivet could be set up in the hole; but the difficulty was to prevent the rivet from setting up outside, particularly with cup riveting. With too light hammer the rivet was liable to spread before setting up in the hole. Once a rivet started to spread, it was impracticable to drive it back to fill the hole. Of two hammers, one with a slow beat and heavy blow, the other with a quicker beat and lighter blow, the slower hammer with the heavy blow would fill up the rivet in the hole far better than the other. He agreed that the introduction of dowel pins frequently led to trouble in taking hammers apart. Hammers without dowel pins were simpler in use. Leakage on permanent pipe lines was inexcusable; it was due to carelessness. On temporary lines leaks were more excusable, since less care was given to putting them up. He regarded strainers on pipe lines as a nuisance. The best place for them was just in front of the tools.

Referring to Mr. Reavell's method of testing hammers he doubted the accuracy of that method, since the spring would hardly rebound quickly enough to record properly the blow of the hammer. There was also resilience and a periodicity of the spring, and, with a quick-beat hammer, the effect would not be a clean curve. Small work on airship had been done successfully during the war by miniature pneumatic tools. Undoubtedly, the rivet bent badly when the weight of hammer blow was too heavy. Self-closing couplings had uses, and tended to economise air, but they were inclined to throttle the flow of air sometimes impairing the efficiency of the tool. He thought no test for pneumatic tools was superior to the drilling test. He had used the apparatus for brake testing and had prepared a table giving result. This would be published in the "Proceedings."

It had been stated that the cost for power of 20*s.* 1*d.* for compressing 100,000 cub. ft. of free air, was low. He had since obtained from an entirely different yard figures which completely confirmed that figure. The immersion of tools in a paraffin bath, to prevent rust had been criticised. Moisture—generally impregnated with fatty acids from the oils—collected in hammers and rusted the tool quickly. The paraffin bath was a quick way of cleaning them. Of course, if the air were dry and clean there would be no necessity for a paraffin bath.

The President then announced a meeting on Monday next, at 7 p.m., of the Graduates' Section (London), at which Lieut.-Colonel E. Kitson-Clark would deliver a lecture on "Literature and Engineering." All classes of members were invited. An informal meeting would take place on Friday, March 7, when a lecture would be delivered by Commander G. C. C. Damant, R.N., on "The Recovery of Gold from the Laurentic." On Friday, March 21, he (the President) would deliver his address. The meeting then terminated.

MOTOR TAXATION.—The Ministry of Transport has issued a table showing under tax categories the number of licences issued by licensing authorities during the twelve months ended November 30, 1923, in respect of mechanically propelled vehicles. The total figures are as follows:—England: annual licences, 735,441; quarterly licences, 744,031. Wales: annual licences, 38,164; quarterly licences, 57,162. Scotland: annual licences, 75,917; quarterly licences, 73,670. The figures exclude tramcars and trade licences and comprise cars taxed on H.P. basis, cycles, invalid vehicles, commercial goods vehicles, road locomotives, motor ploughs, tractors, hackneys and exempt vehicles.

INDUSTRIAL NOTES.

THE agreement arrived at between the National Council of Port Labour Employers and the Transport and General Workers' Union provides that from the date of resumption of work, the minimum daily wage on the half-daily basis is 11*s.* for the greater ports and 10*s.* for the smaller; on and after June 2 next, the figures are to be 12*s.* and 11*s.* respectively. All existing differentials are maintained and are to be added to the increased minima. The permanent men are to be paid the increased rates, the June increase to commence with the week's pay for the first pay-week wholly worked after the introduction of the second increase rate. The increase also applies to the men on piecework. The overtime rates are readjusted in accordance with the increased rates of pay. Local joint committees are to deal with the questions of work and adjustment of rates and, when necessary, to refer them to the National Joint Council. The parties to the agreement are to appoint a sub-committee (the Minister of Labour to appoint an independent chairman and supply such technical assistance as may be necessary) for the purpose of developing and strengthening the system of registration and to examine the proposal for a guaranteed week, with a view to arriving at an agreement to give effect to the Shaw report.

These terms were accepted by the men, and work at the docks throughout the country was resumed last Tuesday. The members of the Stevedores' Union, whose claim was an advance of 2*s.* 6*d.*, have accepted the same terms as the dockers.

In reply to a charge made by Mr. F. Varley, M.P. for the Mansfield Division of Nottinghamshire, to the effect that the Mining Association was doing nothing with regard to the miners' wage increase demand the Association have issued a strongly-worded repudiation. They add that immediately on receiving a notice from the Miners' Federation to terminate the national wages agreement as from April 17, a sub-committee of the association was formed, and the matter has had the serious and continuous consideration of the sub-committee ever since. It was also necessary to obtain the views of the district associations and steps were immediately taken to that end. Further, a joint wages return is being prepared in conjunction with the Miners' Federation to ascertain the rates of wages actually being paid in every grade in every district, the members employed in each grade and the number of shafts worked. By arriving at a preliminary agreement on these important figures, it is believed that time will be saved when joint discussions are resumed. Finally, at the request of the Miners' Federation, a further joint meeting has been fixed for March 6.

The South Wales Miners' Federation have decided to call a South Wales coalfield conference on March 8, with a view to consider the South Wales policy at the national delegate conference on wages which is to be held afterwards. Reports to hand are to the effect that the South Wales miners demand a new minimum wage equal to the rise in the cost of living added to the wage paid in 1914.

With reference to the claim for an advance of 10*s.* per week made by the representatives of the Federation of Engineering and Shipbuilding Trades, mentioned in our issue of last week, the employers proposed that if the claim were withdrawn they would appoint a joint committee to consider the framing of a new agreement, one of the conditions of this to be the provision of a basis upon which general wage fluctuations should be arranged. The Trades Federation met at York last Friday and resolved that they cannot agree to withdraw the application for 10*s.* and pressed for an early meeting to further consider the scheme. They are prepared to appoint a committee (immediately the grant of 10*s.* is made) for framing a new agreement, the basis upon which wage fluctuations shall be arranged in future to be one of the terms of reference. The Southampton shipyard engineers have gone on strike to enforce their claim for an immediate advance in wages of 17*s.* 6*d.* per week, and have passed a resolution for stopping overtime.

Sir Alan G. Anderson, the new president of the Chamber of Shipping, speaking at the annual banquet of the Chamber last Friday, stated that freights in 1923 were about 4 per cent. worse than in 1922, which at one time were supposed to be the worst possible. The reason for this unsatisfactory situation was "too many ships and too little trade."

The Thornham Mills, Royton, were stopped on the 13th inst., following upon the addition of a fourth opening machine to three existing ones which two women operatives had fed hitherto. When the fourth machine was installed, the trade unions concerned claimed 10*s.* 6*d.* per week for each woman; they ultimately reduced the claim to 8*s.* 3*d.* The employers contended that the output of the two women would not be increased by the fourth machine; they decided to grant a longer time for brushing down and cleaning it, and also offered 4*s.* 5*d.* for each woman. The unions not agreeing to this, the mills concerned stopped working. This incident, comparatively unimportant in itself, may have serious consequences, since it was decided at a meeting of the Master Cotton Spinners' Federation held last Tuesday in Manchester, that unless the operatives on strike at the Thornham Mills resumed work within seven days, steps would be taken to close all mills connected with the Federation and to keep them closed until they did resume work. This decision follows numerous attemps made by the Federation to settle amicably the dispute at the Thornham Mills, and would involve as many as 150,000 workers.

In a letter which he has addressed to the Prime Minister, Sir George B. Hunter, of Messrs. Swan, Hunter and Wigham Richardson, Limited, states that skilled shipwrights and other skilled men in the shipbuilding trades are working 47 hours a week for 8*s.* 2*d.* per day. Shipbuilders would gladly increase the wage if it were possible, but owing to the great depression in shipping and shipbuilding, any advance in wage would most probably increase unemployment. Men of similar skill in the house building trades, working only 44 hours per week, are paid 11*s.* 11*d.* per day. The dock labourers, who were paid 10*s.* per day, stopped work to enforce a demand for an additional 2*s.* per day. This will increase the cost of living against the interests of the workers and the poor. Increased wages which cause increased cost of production, adds Sir George, must make it more difficult to improve our export trade and shipbuilding. There are many other wage discrepancies apart from those quoted in this letter, all to the advantage of the unskilled members of the community. To take one instance, the London scavengers have a wage which is not "in the job" by any means, and is above that of skilled mechanics who have had to learn their trade.

According to *The Echo de la Bourse*, Brussels, a Bill has been introduced in the Belgian Parliament, to increase the working day from 8 to 9 hours for a period of three years. The bill also proposes to increase the income tax of those persons whose revenue exceeds 12,000 francs. Our contemporary explains the two conditions here stated as follows: "There are people, especially in Parliament, who are of opinion that the increase in the working day means a sacrifice required on the part of manual labour, hence the "compensation" in the shape of increased taxes to be paid by other members of the Community. The manual worker will work longer hours; on the other hand, the non-manual worker will pay more, and the contentment will be general. But the Belgian workers have never viewed with satisfaction the rigid imposition of the 8-hour day, and in order to benefit by the 10, 12, and sometimes 15-hour day, 150,000 of them have left Belgium for France. By lengthening the working day to 9 hours no sacrifice is required on the part of Belgian manual labour, and no compensation was required either, a compensation which simply means a capital levy imposed upon a class of people who already are singled out by the Treasury, and which will have the effect, if the bill is passed, to disorganise the whole financial, industrial and commercial system of the country."

We read in *The Iron Age*, New York, that total disbursements made by the United States Steel and Carnegie Pension Fund, applicable to employees of the United States Steel Corporation for 1923, amounted to 1,448,113 dols. Pension cases continued beyond December 31 numbered 4,054, of which 576 were added during 1923. The average age of beneficiaries over the period since the establishment of the fund in 1911 is 66·4 years; average service 31·6 years; average monthly pension 26·90 dols.

In addition to our note on page 248 *ante* with reference to the remarks made by the Secretary of the Boilermakers' Society, in the matter of Dutch shipbuilding, we may state that information reaches us to the effect that a Dutch shipbuilding firm has recently received an order for the building of a large twin-screw tank steamer complete with engines for a British company.

THE FORD INDUSTRIES.—According to *Iron Trade Review*, Cleveland, Ohio, the Ford Company has 162,792 men employed in its various industries. Of this total 121,214 are in manufacturing plants of the company within the United States, and 24,323 in American branches. Employees in foreign lands number 11,028. There are as many as 68,285 in one of the company's works.

SALARIES PAID IN THE ENGINEERING PROFESSION.

THE Society of Technical Engineers send the following communication for publication: The Society of Technical Engineers has taken a census of the salaries at present paid in the engineering profession. A summary of the information collected on the subject is given in the following table of the salaries of staff engineers, 1923:—

Age.	Table I. Average for all Engineers.	Table II. Average for Assistant Engineers.
	£	£
22	150	150
24	195	185
26	240	220
28	285	255
30	325	285
32	365	315
34	400	340
36	430	355
38	460	370
40	485	380
42	505	390
44	520	395
46	535	400
48	545	400
50	555	400

Table I is arrived at from all the figures returned, including salaries as high as 1,500*l.*, and covers staff engineers in many different sections of engineering. Table II gives the average salaries paid to assistant engineers engaged in electrical manufacturing. Most of those covered by the returns are fully qualified men who have had a training as long and expensive as that necessary for other professions, but their incomes are much lower, being insufficient to enable them to maintain a suitable standard of living or to allow them to train their sons for entry to the profession.

The work of the technical engineer is in large measure the key to the success of modern industry, but unless steps are taken by those most closely concerned to improve materially the existing standard of salaries it will neither be possible to continue to recruit the right type of men for the profession nor to prevent present discontent within its ranks from increasing to a serious degree. It is common knowledge among staff engineers that under present conditions their work is hampered by anxiety as to their personal finances. A considerable increase in salaries would add very little to the cost of the manufactured product, and this would be much more than compensated for in a short time by increased efficiency.

The Society appeals for the support of all members of the profession in its efforts to raise the existing standard of salaries, and looks for the co-operation of all employers to the same end. It is not a militant Trade Union and does not believe in the use of the strike weapon for the promotion of its objects. Rather, on account of the strength of its case, it expects to establish better conditions by friendly negotiations with those responsible for the financing of the engineering and allied industries, as well as by the pressure of enlightened public opinion and the support of the engineering profession as a whole.

SOCIETY OF CHEMICAL INDUSTRY.—A meeting of the Chemical Engineering Group of the Society of Chemical Industry is to be held on Friday, March 7, in the Engineers' Club, 39, Coventry-street, London, W.1. At the meeting two papers will be read and discussed, namely, (*a*) "Adsorbents, with Special Reference to Silica Gel," by Professor E. C. Williams (Ramsay Professor of Chemical Engineering at University College, London); (*b*) "The Applications of Activated Carbon in Industry," by Major V. F. Gloag. The meeting will commence at 4.30 p.m. by the reading of the papers. At 6.45 p.m. an informal dinner will be held in the Club premises, and at 8 p.m. discussion on the two papers will commence. Mr. J. Arthur Reavell, M.I.M.E., M.I.Chem.E., chairman of the group, will preside.

THE LATE SIR ROBERT ROPNER, BART.—The well-known North of England shipowner and shipbuilder, Sir Robert Ropner, Bart., died at Preston Hall, Stockton-on-Tees, on Tuesday last in his 86th year. He was the son of Mr. John Henry Ropner of Magdeburg, and was educated in Germany. Coming to England in his youth he settled in Stockton, and after a partnership in the shipping trade with Mr. Thomas Appleby, he founded the firms of R. Ropner and Company, shipowners, and the Ropner Shipbuilding and Repairing Company, at Stockton. Success followed his effort, and he was able to devote a part of his time to public affairs, representing Stockton in Parliament for ten years. He was a great benefactor to the district in which his work was conducted and Ropner Park, Stockton, which he presented at a cost of 50,000*l.*, forms a memorial to his generosity and the interest he had in the general welfare.

THE INSTITUTION OF CIVIL ENGINEERS.

*The Measurement of the Discharge of the Nile through the Sluices of the Assuan Dam.**

By HAROLD EDWIN HURST, M.A., D.Sc., and DAVID ALEXANDER FRASER WATT.

IN a previous paper† a method was described of measuring in a masonry tank the discharge through certain sluices of the Assuan dam, and so determining the whole discharge of the Nile. Such a method can only be applied during the low stage from January to July, and is not applicable to the discharge of the Nile in flood time, which is known with far less certainty than the low-stage discharge. The present Paper describes the first measurements of the higher stages of the Nile made by a method depending ultimately on direct measurements of volume in a masonry tank.

A current-meter of propeller type and of specially stout construction was used to map the velocity-distribution in the sluices. By doing this in an R.L. 100 (type A) sluice, the discharge of which has been measured in the tank, the current-meter is rated against absolute volumes of water. Knowing the area of cross section of the sluice-jet, the relation between the velocity of the water and revolutions of the current-meter is obtained. Repetition of the process in other sluices enables the discharge of these to be inferred.

The velocities ranged from 3 to 6 m.p.s., and over this range the rating curves of the current-meters were linear. A good degree of accuracy was obtained, both in the rating and in the actual measurements of unknown discharges.

Type C and type D sluices, which are used to pass the discharge in flood time, are 7 m. high and 2 m. wide, and have their sills respectively at R.L. 92 and R.L. 87·65 m. During this time all sluices are fully open; there is no regulation, and the downstream and upstream levels depend only on the quantity of water passing. The conditions of flow through type C sluices were those of a broad-crested weir with the downstream level above the crest of the weir, while the conditions for type D ranged from those in which the entrance is just submerged to those in which the exit is just submerged.

Two sluices of each type were chosen for experiment, and the differences in discharge between those of a type ranged from 0 to 10 per cent. The reservoir-levels ranged from about 95·3 to 98 m., and over this range the relation discharge and head for type C sluices was linear. This relation was also closely represented by

$$Q = c\,b\,H^{1\cdot5},$$

where b denotes the width of the sluice, H the head above the sill, and c is a constant which was 1·48 in one case and 1·53 in the other.

For a type A (R.L. 100) sluice discharging into air at the downstream face of the dam the same formula holds, but

$$c = 1\cdot73.$$

In the case of type D sluices, where the sluice is partially submerged downstream, an equation

$$Q = c\,A\,\sqrt{2\,g\,(H - F)}$$

was found, where A denotes the area of the sluice-opening, and c and F are constant. For the sluices examined c and F were found to be 0·84 and 6·06 in one case, and 0·75 and 6·00 in the other.

That formulæ depending only on the upstream level can be found is due to the fact that the downstream level is dependent upon the upstream level.

The velocity-distributions over the sluice-jet near the plane of the sluice-gate have the following characteristics:

Type A (R.L. 100) sluice discharging into air.—The velocity increases fairly uniformly from the upper surface to the bottom. The equal-velocity lines run from side to side of the sluice, with a dip in the middle.

Type C (R.L. 92) sluice, submerged weir conditions.—In the case of one sluice the approaching stream was normal to the dam and in the other inclined. In the latter case the velocity-distribution is unsymmetrical. In both sluices on the average the velocity increases from the surface to the bottom, but the distributions are not so regular from one experiment to another as in type A sluices.

Type D (R.L. 87·65) sluice, partially submerged downstream.—In one case the approaching stream is normal to the dam, and in the other inclined. In the latter the velocity-distribution is unsymmetrical. The most marked feature of the sluice with the normal approach is that the velocities at the sides of the sluice are higher than those in the middle.

In all types of sluice on the average the maximum and minimum velocities over the cross-section depart from the mean by 10 to 15 per cent. The cause of the variation in discharge between sluices of the same type has not yet been properly established. It may be due to the variations in the amount of turbulence, variations in the river-bed upstream, and variations in direction and velocity of approach. Classification of the sluices according to the state of the bed and the direction of approach enables the discharge through the dam in flood time at different upstream levels to be estimated. Supposing all sluices to correspond in discharge with the greater of the pair measured, and also with the smaller, the following figures obtain for comparison with the adopted discharge:—

Maximum estimate	...	...	...	104·5
Adopted	,,	...	...	100·0
Minimum	,,	...	...	97·0

* Abstract of a paper to be read before the Institution of Civil Engineers on Tuesday, March 4, 1924.

Minutes of Proceedings Inst. C.E., vol. ccxii, p. 228.

The experimental sluices were chosen as far as possible to represent extreme conditions of approach. Taking this into account, the probable error of the estimated total discharge has been found to be on the average about 1 per cent. During the flood season of 1923 it was hoped to measure the discharge of one sluice in nearly every set, so that the cause of variation in discharge may perhaps be traced, and all uncertainty as to the magnitude of the discharge removed.

For a number of years measurements have been made with current-meters of the Price pattern in the ordinary way at a station 35 km. below the dam. These can now be compared with the present experiments. The results are shown in the Table below.

It appears, therefore, that up to discharges of about 9,000 cu. m. per sec., corresponding with a mean velocity of the river at the discharge-site of 1·7 m. per sec., the two methods of measurements agree very closely, but above that point the current-meter discharges are much higher than the sluice discharges. This is probably due to the velocity indicated by the current-meters being too high, as the cross-section of the river corresponds with sections taken before and after these observations. Further investigation of current-meter measurements at these high velocities is needed.

Comparisen of Sluice Discharges and Current-Meter Discharges.

Range of Reservoir-Level.		Mean Reservoir-Level.	Number of Current-Meter Discharges.	Mean Discharge by Current-Meter.	Mean Discharge by Sluices.	Correction to Current-Meter.
				Cub. M. Per Second.	Cub. M. Per Second.	Per-centages.
below	95·75	95·43	24	5,660	5,560	−1·8
95·75	96·25	96·05	22	6,720	6,700	−0·3
96·25	96·75	96·51	39	7,560	7,540	−0·3
96·75	97·25	97·00	22	8,500	8,390	−1·3
		Total	107		Mean	−0·9
Above reservoir-level 97·25 the following discharges were measured in 1922:—						
		97·46	1	9,980	9,160	−8·2
		97·61	1	10,350	9,420	−9·0
		97·79	1	11,460	9,720	−15·0
		97·99	1	11,950	10,040	−16·0

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*"The Similarity of Motion of Water through Sluices and through Scale Models; Experiments with Models of Sluices of the Assuan Dam."**

By H. E. HURST, M.A., D.Sc., and D. A. F. WATT.

IN a previous paper† a description was given of the direct measurement of the discharge of one of the sluices of the Assuan dam by means of a large masonry tank. The discharges so measured ranged from 1 to 96 cub. m. per sec., and the heads from 30 cm. to 13·5 m. above the sill of the sluice. The size of the sluice is 3½ m. high by 2 m. wide, and it discharges into air at the downstream face of the dam.

Six models of this sluice have been made to scales of 3/200, 1/50, and 3/100, in wood, wood and metal, and metal. Experiments on these models have been carried out, in which the head of water is to the same scale as the model, and they cover all conditions of head and gate-opening occurring in the original tank experiments. The general result is that, if n denotes the ratio of the linear dimensions of the actual sluice and of its model, and Q and q their discharges under corresponding conditions,

$$Q = n^{\frac{5}{2}}\,q.$$

If the experiments are arranged in groups of six according to head and opening, the maximum departure of the mean of any group from this relation is 5 per cent. when the sluice-opening is running full and is not acting as a weir. Excluding flow under weir conditions, the mean departure for all models is 0·4 per cent., and the mean departure, disregarding sign, is 1·5 per cent.

With flow under weir conditions lower velocities occur, and although at the higher heads the above relation holds, yet, as the head and velocity decrease, a point is reached below which the relation is rapidly departed from. On the models used this point occurs with a head of about 3 cm. above the sill of the sluice. Below this head the discharge of the models rapidly decreases relatively to that of the actual sluice.

The surfaces of the models were all smooth to the touch, but some experiments were carried out after roughening the surface of one model with coatings of sand of two grades of fineness. The mean diameters of the grains in these two grades were estimated at 0·25 mm. and 0·5 mm. On the average the effect of these coatings was to reduce the discharge by 3½ per cent. and 6 per cent. respectively; but the effect varied with the head and the amount of opening of the sluice-gate. Thus in using models for the study of discharge it is necessary to consider the surface of the original, but it may be taken that brick or smooth-dressed masonry requires a surface on the models which is smooth to the touch.

It has been shown that the discharge of a sluice of the Assuan type is represented by the formula

$$Q = c\,A\,\sqrt{2\,g\,(H - F)}$$

where H denotes the head above some fixed point, A is the area of opening, and c and F are constants for any particular condition of sluice-opening. The results of the model experiments show that c is the same for model and full-scale conditions, and that $\frac{F}{H} = n f$, f being the value for the model.

In the case of the actual sluice, when the gate is fully open, an instability has been discovered. Over a range of about 3 m. in head the discharge can have either of two values differing by about 7 per cent. The conditions which determine which of the two modes of discharge will occur have not been discovered. The phenomenon does not occur on the models, of which the discharges correspond with a discharge about midway between these two modes.

The similarity of discharges existing over a large range of conditions implies similarity of form of jet, similarity of velocities, and consequently similarity of energy partition. The theory of the flow of water through a sluice can be discussed by stating the energy equation for the vertical plane at which the pressure energy is zero. Using capital letters for the actual sluice, and small letters for the model, let

R r	denote	skin friction per unit area of wetted surface.
V v	,,	velocities at the plane of reference.
A_1 a_1	,,	area of cross-section of the jet in this plane.
S s	,,	wetted area of sluice-walls upstream of this plane.

Then Q is only exactly equal to $n^{\frac{5}{2}}\,q$

when $$\frac{r}{v^2} = \frac{R}{V^2}.$$

If $\frac{r}{v^2}$ is not constant, there will be departures from similarity of discharge and probably from similarity in form of jet and velocities also. If the whole of these departures from similarity are put into the resistance term which causes them,

$$Q = n^{\frac{5}{2}}\,q\,\left\{1 + K\left(\frac{r}{\rho\,v^2} - \frac{R}{\rho\,v^2}\right)\right\}$$

where $K = \frac{S}{A_1} = \frac{s}{a_1}$ (approximately).

By mapping the water-surface on the models, approximate values of K have been found.

Values of $\frac{r}{\rho\,v^2}$ and $\frac{R}{\rho\,V_2^2}$ can be found from experiments by Messrs. Stanton and Pannell* on pipes, so that the form of the correction $K\left(\frac{r}{\rho\,v^2} - \frac{R}{\rho\,V^2}\right)$ can be obtained.

It is found that the correction calculated from the work referred to agrees roughly in form with the result of the model experiments, and this is as much as can be expected, for the following reasons:—

1. The errors of experiments with the models on flow under weir conditions are fairly large.

2. In the pipe experiments the liquid has fixed boundaries, and the velocity along the pipe is constant. In the weir experiments the boundary is not fixed, but is determined by the relation between frictional resistance and the other forces, including at the very low heads surface tension, which latter has no effect either in the pipe experiments or on the full-scale sluice.

The following conclusions have been formed:—

1. Models can be used to determine the discharge of large sluices with an average accuracy as good as that obtainable by current-meter measurements.

2. The scale of the model depends upon the product of the velocity in the actual sluice and its linear dimensions. The limit of smallness in the foregoing experiments occurs with weir conditions where the head above the sill is about 3 cm., the depth about 2 cm. at the gate, and the velocity about 0·4 m. per sec. Until further experiments on models of other structures define the limiting conditions more closely, it will be well to keep the product of velocity, in cm. per sec., and smallest dimensions of the orifice, in cm., above, say, 100, and in general not to use orifices of less than 3 cm. in their small dimension.

3. In designing regulators, barrages, or dams, the sluiceways and gates should be as simple as possible, with no projecting pieces or intricate details. The construction of a model will then be easy, and there will be no necessity to omit small features of the original which may affect the discharge.

4. Models provide a cheap means of studying many other hydraulic questions on a manageable scale, as, for example, the effect of river-training works, silting and erosion of river- and canal-beds, and flow of the subsoil water.

* Abstract of a paper to be read before the Institution of Civil Engineers on Tuesday, March 4.

† Minutes of Proceedings Inst. C.E., vol. ccxii, p. 228.

* Collected Researches of the National Physical Laboratory, vol. xi, 1914.

THE SOUTH WALES COAL BUYERS HANDBOOK.—This is a guide to the coal, coke and patent fuel trade of South Wales, for salesmen, buyers and users. It gives the sources of supply of the commodities, their treatment, trade names, characteristic features and other useful information. The book is edited by Mr. William Phillips, and is published by him at Primavesi-chambers, West Bute-street, Cardiff, at the price of 10*s*.

WAREHOUSES IN ROUMANIA.—The Commercial Secretary at Bucharest has forwarded a list of warehouses in Roumania officially recognised as places where goods could be deposited and from whence a Customs entrance in Roumania could be made. These warehouses approximate, therefore, to the bonded warehouses in the United Kingdom. The list may be consulted by British firms interested in Roumanian trade on application to the Department of Overseas Trade, 35, Old Queen-street London, S.W.1. (Reference 12325/F.E.)

TRACTION ACROSS ROUGH AND ROADLESS COUNTRY.*

By L. A. LEGROS, O.B.E., M.I.Mech.E.

THE years that immediately preceded the War saw the commercial application of two methods of traction which, though widely different, were devised for the same object—the transport of heavy loads, and even of artillery over bad roads, marshes and uneven land. These methods comprised various types of four-wheel drive tractors and lorries and also many developments of the chain-track vehicle of which the "tanks" and chain-track artillery are examples of the most highly specialised forms.

Country devoid of roads presents widely different difficulties to traction arising from the character of the surface which may vary from hard plutonian rock to friable conglomerates or soft material such as chalk. The rock may be covered with a layer of variable thickness; in hot countries of dust, sand and stones of all sizes; in temperate climates of earth or clay; and in Northern climes by powdered snow, crusted snow and ice, the latter varying from the smooth surface of a frozen pond to the hummocky and crevassed ice of the glacier. Not only do difficulties arise from the gradients and irregularities of the surface, but to these may be added those due to forests and undergrowth.

The chief obstacles to traction across country may generally be divided into the following classes:—(1) Light powdery snow, such as is found in winter throughout Canada, Alaska, Russia and Siberia as well as locally in some other countries; snow of this kind presents the most difficult problem and from the designer's point of view it closely resembles that of very soft marshes. (2) Deep sand that forms shifting dunes, of which the deserts afford examples. (3) Pebbles and rounded stones that roll on each other and present a peculiar difficulty to adhesion. (4) Large irregularities, hills and valleys, that involve long climbs and descents, stoppages for route selection and occasionally reverse running over part of the route that has been covered. (5) Minor irregularities, gullies, shallow water courses, and small ridges which throw the axles out of parallel. (6) Dry and, at high altitudes, rarefied air which absorbs little heat from the radiators and jackets of the engine; (7) The carriage of a useful load of from one to two tons in addition to supplies for a radius of two or three hundred miles (8) Finally the vehicle before leaving the road may be required to travel over a section of mountain road with hairpin bends that necessitate a turning-circle of small radius.

It is generally recognised that in virgin country where roads are non-existent, such as large areas of Canada and Siberia, transport can be most readily effected in the winter. The rivers and watercourses then being frozen cease to present an obstacle and the crossing of enormous wastes of snow—given a tractor capable of travelling over snow and ice—only necessitates selection of a route that avoids large obstacles. These conditions are to be found in some of the mountainous parts of Europe, for example in the Alps and the Pyrenees, on a sufficiently large scale to permit of carrying out experiments.

Another and very important variety of long distance cross-country traction is that of crossing large deserts. In North America the Alkali deserts have been crossed by four-wheel drive vehicles over a width of 150 miles. Australia has its deserts of great extent; Asia has several, that of Arabia being crossed by caravans and pilgrims to Mecca, but the Sahara probably presents the greatest difficulty because the distances are so large. Water has apparently become more scarce within historic times, and routes that were frequented by caravans in the time of Charlemagne have now become both difficult and dangerous for camel transport. Nor is the surface all smooth sand, it varies from shifting sand to hard sand, from small stones to big rocks, from the rough beds of rivers, that now flow only occasionally, to the mountains of the Hoggar, and finally from scrub to the marshy ground in the vicinity of the oases.

Fig.1.

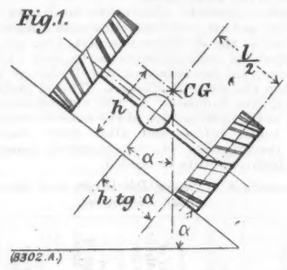


Fig.2.

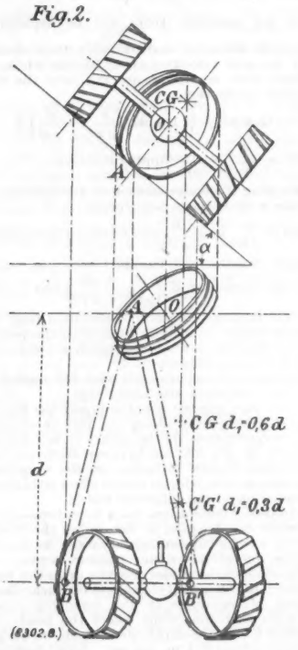


Fig.3.

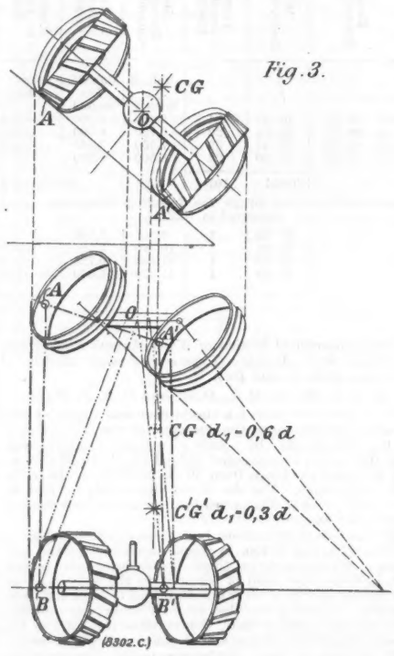


Fig.4.

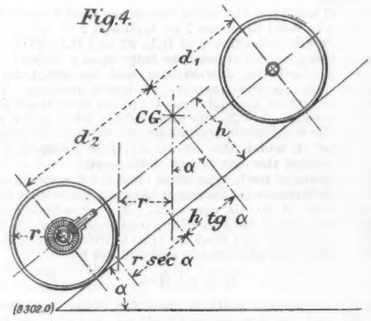
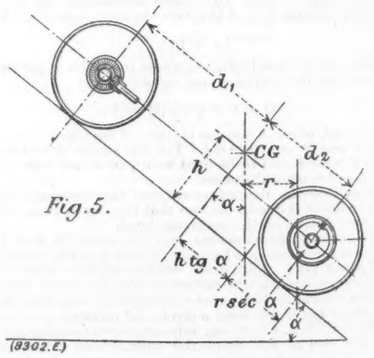


Fig.5.



In order to define the problem it is necessary in the first place to decide the maximum gradient the machine is to climb and the maximum resistance to traction that is to be expected from the ground. A man can climb a rough surface at 45 deg. without using his hands provided the foothold is good; hence in some of the early attempts at traction across country, and even in early locomotives for use on rails, use was made of feet. In more recent time this method was applied by Diplock in his pedrail, which was fitted with pivoted spring-supported feet transferring the load through rollers to a cam-path.

The climbing of steep gradients on railways by means of the rack and pinion, though introduced by Blenkinsop in 1811, required materials and workmanship beyond the range available at that date; later, however, the rack railway found its place in facilitating the ascent of mountains in Switzerland, and in France where gradients of 25 per cent. (about 14 deg.) are in regular use. Traction on smooth wheels, or adhesion traction, appeared at first sight impracticable and Brunton and several other inventors designed machines to be propelled by feet. The demonstrations made by Hedley on a wagon fitted with smooth wheels, driven through gearing by a windlass proved the possibility of hauling ordinary trains on gradients of 1 in 30 (about 2 deg.). Later, towards the end of the nineteenth century the electric tramcar fitted with powerful slipper brakes was improved till capable of working traffic on lines having gradients of 1 in 10 (about 6 deg.); in all these cases except that of the rack railway the limiting grade is determined by the slipping of the wheels.

GENERAL CONSIDERATION OF THE PROBLEM.

In dealing with traction across country it should be remembered that the description of the grade as a percentage for steep gradients must be measured as the sine of the angle and not, as on railways, by the tangent. It is necessary to provide projections on the wheels, chain-tracks or belts, such as strakes, spuds or "grousers" to ensure that sufficient resistance shall be given by the ground itself, for it is the resistance to shearing of the clods or cakes of earth between the spuds that forms the reaction necessary for the advance of the tractor and determines the gradient that can be climbed, provided there is margin of power in the engine and that the reduction gear is appropriate. At the commencement of this century the automobile fitted with pneumatic tyres proved its capability in climbing gradients up to 25 per cent. (about 14 deg.); in some of the later agricultural tractors the effort transmitted to the drawbar amounted to as much as 80 per cent. of the weight of the tractor; now if we allow 20 per cent. of the total effort applied to the axle as the loss in earth resistance, a figure which experience has shown to be reasonably near the truth under conditions which commonly occur in practice, it will be seen that the total effort at the periphery of the driving wheels may be taken as equal to the weight of the tractor. At present even with four wheels driven this turning moment is the maximum that can be adopted, for reasons which will appear later. This *particular* value, on the ground of reasonableness and simplicity, has been adopted in the diagrams that follow, diagrams that deal with the static question of stability in ascending, descending, skirting and turning on a slope. Moreover, although gradients of 45 deg. have been climbed by several tractors, a slope of 40 deg. only has been taken in the diagrams in order to facilitate reference when considering other gradients.

For traction on powdered snow the intensity of load should approach 0·75 lb. per sq. in., which is the figure determined by practice in the case of wooden ski. If, however, the temperature rises to near zero the snow will commence to bind and to adhere to metal surfaces; when the snow is absolutely moist fur-covered ski must be used by the runner to prevent adhesion of the snow. When the snow surface has thawed and frozen again and a surface of *névé* is produced, the pressure of 0·75 lb. per sq. in. will not penetrate the crust, and this cause may diminish the adhesion and consequently the maximum gradient climbable by a tractor constructed for work on powdered snow. Ice and glaze (*verglas*) may, moreover, necessitate the use of non-skid chains or their equivalent.

The resistance of the ground is a factor regarding which very little indeed is known; even though figures were obtainable they would not help the driver, though research on the subject would be of advantage in determining the best form of spuds for use on agricultural tractors and on certain specified soils. The cross-country driver must estimate the angles and resistance, just as the automobile driver must estimate the resistance to slip of a road surface from its appearance, camber and gradient. The designer can, however, make the machine reasonably safe by reducing the more dangerous risks to a minimum.

Fine sharp sand, of recent origin, such as occurs in river beds, will bind and become firm under pressure; this is not the case however with the wind-blown sand of the desert, the particles of which become rounded and form a continual source of danger to wheeled vehicles such as the ordinary automobiles, which will "dig itself in" with little or no warning; yet under slightly different conditions a patch of sand that will carry a car easily may become a quicksand when wetted, and

* Paper read before the British Section of the Société des Ingénieurs Civils de France on February 20, 1924.

another that could not be crossed when dry, may have become practicable after a shower. The pebbles of the seashore have similar disadvantages; they are unstable under the load and slight slipping causes "digging in" which is the worse the rounder the pebbles; the only cure is to provide very large track surface so that the pressure per sq. in. of bearing area may be kept low.

The crossings of ranges of hills require long climbs which generally involve a variety of gradients and depth of soil and, in temperate climes, of vegetation also. It happens sometimes that the clods of earth shear from the sub-soil at the bottom of the roots of the vegetation and that a change of route or of type of spud may be necessary. Small irregularities in the ground will, on the other hand, put the axles in winding if crossed obliquely or tend to throw the tractor on its side if crossed at a small angle. If these irregularities coincide

FIG. 6.

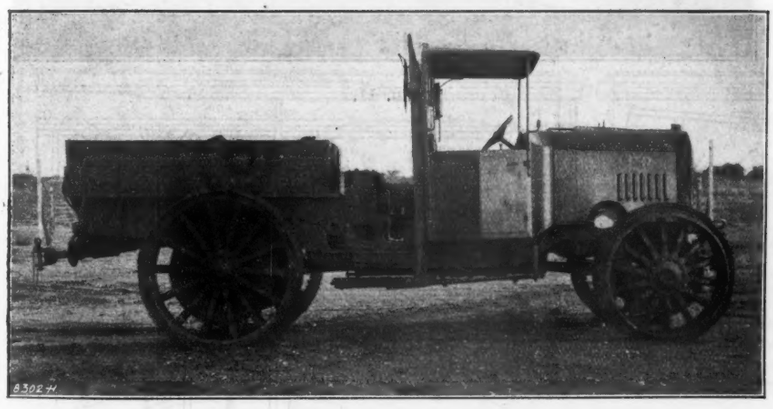


FIG. 8.

in pitch with the wheelbase or if the summits are but slightly rounded the vehicle will be liable to ground or to touch on the lower parts between the wheels; for this reason the question of providing as large under-clearance as possible is of great importance. On country covered with large stones it is necessary that the brakes and brake gear should be so arranged as to run the minimum risk of damage.

Dryness of the air due to severe frost or to great heat reduces the rate of heat-transference in the radiator, and this effect may be accentuated by rarefaction of the air, as on mountain passes and on high plateaus (Johannesburg); for some conditions the addition of a condenser may be necessary.

After consideration of all the difficulties that have to be confronted in consequence of the absence of roads it would appear that the solution of the problem depends more on the information to be obtained from actual experiment than on inference from existing data; the problem becomes as closely allied to sport as to engineering.

Up to the present no machine has been constructed that is capable of overcoming all the obstacles described, though several show great advance in the surmounting of more than one of the classes of difficulty mentioned.

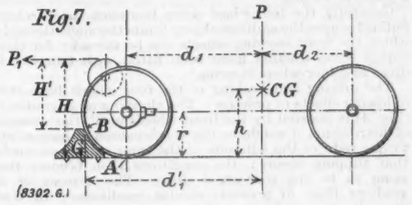
From a consideration of these difficulties we may examine the qualities that the cross-country tractor possess: (*a*) Stability on gradients; side-lying (or skirting); (*b*) Stability on gradients, climbing under power and descending with brakes; (*c*) Height for the coupling for hauling a trailer; (*d*) Driving on all four wheels; (*e*) Capability for crossing minor irregularities; ditches and trenches; (*f*) Ability to cross loose and soft ground without "digging in"; (*g*) Accessories for taking maximum advantage of the resistance of the ground to shearing; (*h*) Auxiliary apparatus, such as pads, or rings encircling the strakes, for use on the roads; a winch and scotches for step-by-step advance, or for getting out of difficulties; (*i*) Crossing streams or flooded country; (*j*) Ability to take hairpin bends on mountain roads.

This list is not complete because any highly specialised tractor may, through some peculiarity of construction, introduce a fresh problem. Each of the difficulties taken individually could be overcome easily were data available for the resistance of the snow, earth, sand or marsh to vertical loading and to shear under that load, but, unfortunately, data are almost wholly wanting and with one or two exceptions they vary between wide limits; there are, moreover, difficulties in harmonizing the constructional features of the design so that the best compromise may be obtained, from the practical point of view, for some conditions which are incompatible, for example under-clearance, ability to take sharp curves, and stability in skirting gradients.

(*a*) *Stability on gradients.*—At rest the vertical through the centre of gravity must fall within the trapezoid of which the points of contact of the wheels form the vertices; on rock the areas in contact are small, but on ground on which the sinkage may be 2 in. or more the centres of pressure lie within large areas over which the pressure is neither uniform nor constant. It is necessary to consider stability in climbing descending and skirting gradients; nor can the case of turning on the gradient be overlooked. For this reason it is advisable to take the width of track as being the centre to centre distance of the treads of the wheels or tracks, or, in the case of wheels of exceptional width, to deduct 12 in. or more according to the conditions from the overall width to arrive at the effective width for the consideration of problems of stability. This investigation enables a relationship to be established between the height of the centre of gravity and the width of track; it limits the height of the centre of gravity and for a given height determines a minimum width of track. The conditions shown in Fig. 1* on the opposite page require that $l/2 > h \tan a$.

A very brief examination shows why the three-wheeled vehicle is generally wanting in stability on gradients†. Fig. 2 shows the vertical through the centre of gravity falling outside the base under conditions of driving backwards or using the brake in forward running when skirting a grade. With the centre of gravity at 0·6 of the wheelbase in front of the back axle (as is common

Fig.7.



in tractors) the vertical falls outside the triangle and even though the centre of gravity be carried back through half this distance stability is not ensured.

The case of a four-wheeled tractor with a pivoted front axle (Fig. 3) is more favourable, for in this case the vertex of the base triangle is determined by the perpendicular through the pivot of the axle; in the figure the positions of the vertical are shown for the same positions of the centre of gravity in relation to the back axle as were taken in Fig. 2. The diagrams show how small a margin exists for allowance for dynamic forces and consequently the necessity for running at very slow speed under the more severe conditions. It is in this respect only that they have much educational value. The requirements under the head of stability are low centre of gravity together with wide wheelbase.

(*b*) *Stability on grades when ascending under power and descending with brakes.*—The distribution of the load varies also with the dynamic forces introduced by driving and braking. Thus in forward running or low gear and when brakes are used on steep grades the turning moment on the wheels may equal the weight of the vehicle acting at the radius of the wheel. When under the conditions shown in Fig. 4 ($h \tan a + r \sec a > d_2$) the front wheels will lift. This actually happened on hills with some of the early low-geared short-wheel base cars and has more recently proved the cause of fatal accidents with agricultural tractors. To reduce this risk the centre of gravity must be placed further forward. When under these conditions the vehicle is fitted with brakes on the rear wheels the load on these will be reduced and slipping may occur probably followed by side-slip. If on the other hand front-wheel brakes are fitted the conditions will become more serious when the brakes are applied suddenly. In the example shown in Fig. 5 a braking effort equal to the permissible climbing effort would overturn the tractor.

The limiting case under these condition is that of the so-called two-wheeled tractor (Fig. 6), loaded at the end of the chassis to about 2·5 cwt. plus the weight of the driver, say 4 cwt. in all, which will rise and lift the driver into the air under a light application of the brake. In this case the motor is placed so far forward that its casing comes into contact with the ground before harm can occur. Actually this arrangement enables this form of tractor, when combined with the ploughs as shown to be handled with the greatest ease and to be turned in a minimum width of headland. The requirements under this head are long wheelbase and low centre of gravity limited to a minimum distance from each end of the wheelbase.

(*c*) *The height of the coupling when hauling a trailer.*—The pull on the drawbar is generally applied at the height of the coupling and parallel to the ground surface; when the earth presents sufficient resistance to shearing for the tractor to exert its maximum drawbar pull the front of the tractor will lift if the coupling is placed too high; this will occur when (Fig. 7) $P d_1 > P_1 H$; it is therefore necessary to place the drawbar low, though under the conditions assumed for maximum torque it may be at the height of the axle.

When the tractor is fitted with a winch for hauling itself or another tractor over difficult country or out of trouble, the usual arrangement is for this to be fitted at the back and to lead the rope on to the top of the drum for convenience in laying the coils; the height of the rope may consequently be considerably above the axle and in this event scotches are used with hollow faces embracing about one-sixth of the circumference of the wheel and fitted on the underside with spikes or spuds to gain adhesion from the ground. With this arrangement the front of the tractor will not lift provided that $P d_1' > P_1 H'$.

The requirement under this head is a low position for the draw-gear; but the gear cannot be placed below the

* An angle of 40 deg. has been taken for the slope in this and the other figures, for facilitating reference, but several machines are actually capable of dealing with gradients of 45 deg.

† The general statical and dynamical problems relating to tractor traction have been dealt with in considerable detail by J. Jandasek, Automotor Industries (America), Farm Tractor Design, June 12, 1919.

axle as in ploughing machines because this would reduce the under-clearance.

(*d*) *Driving on all four wheels.*—Many four-wheel-drive tractors and lorries with four-wheel brakes were in use during the war, a large number being of American origin. This arrangement enables greater adhesion to be obtained and facilitates climbing and descending gradients, but it introduces considerable complication into the front axle which in addition to steering has to comprise driving and brake gear. The Germans used powerful four-wheel-drive tractors in the war, one of the best examples being the Mercedes, shown in Fig. 8; this had front wheels 47 in. and rear wheels 53 in. diameter corresponding reduction ratios being used in the drives. The width of tyres was 12 in. to 14 in., weight 6 tons, and the motor had four cylinders giving 75 h.p. The gear box had two ranges of change giving 8 speeds in all; this tractor could climb a grade of 20 deg.

Generally the four-wheel drive increases the turning radius because the additional gear limits the angle through which the front steering wheels can be turned; for this reason some tractors have been fitted with four-wheel drive and four-wheel steering*.

The driving and braking of the four wheels have the following effects in practice: The climbing of a gradient (Fig. 4) is assisted by the front wheels until the change of distribution of weight on the wheels caused by increasing torque reduces the adhesion of the front wheels so much that slipping occurs; the conditions then become the same as in the rear-wheel drive. The descent of a gradient (Fig. 5) presents similar conditions; in this case also the application of the brakes may change the weight distribution to such an extent that the adhesion of the rear wheels is lost and slipping occurs.

(*e*) *Capability for crossing minor irregularities.*—It happens rarely that ditches or water-courses can be crossed at right angles by a tractor, and on an oblique crossing the descent and climb out may tend to throw the axles and chassis in winding (Fig. 9). The difficulties thus introduced by overloading some of the springs may be overcome to some extent by pivoting the front axle about a pin, having its axis parallel to that of the tractor as shown in Fig. 10. It is essential that this movement should not cause interference with the steering. The tractor must be capable of running over rough ground strewn with stones and rock, and this requires that the under-clearance shall be large and not reduced by any projecting parts, such as brakes or steering gear when on irregular ground.

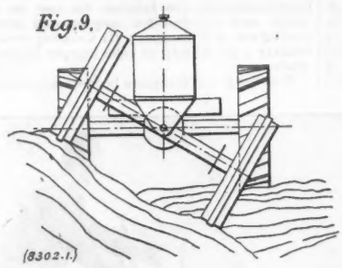
(*f*) *Ability to cross loose and soft ground without "digging in."*—Chain-track tractors have been constructed with so large a bearing surface that they can cross marshes in which a horse or even a man would sink. Wheeled vehicles will generally sink in snow or soft sand because the wheels present an insufficient area, owing to smallness of diameter and narrow width of tread; the area under pressure for the same sinkage varies directly as the width, but only as the square root of the diameter (approximately). Of the two variables it is generally preferable to increase the width; an extreme case designed for crossing sand is shown in the Pavesi lorry, Fig. 11. A wheel sinks less readily in sand than in snow, but the tractive effort at the drawhook diminishes rapidly with the sinkage particularly when the particles of the sand are rounded and dry; pebbles are even more troublesome, and though adhesion chains give some additional help they accelerate the "digging in" once adhesion is lost. For this reason the chain or belt track has advantages on ground for which abnormal wheel-proportions would be necessary.

(*g*) *Accessories for taking maximum advantage of the resistance of the ground to shearing.*—Very little is known regarding the resistance of earth to shearing; greater depth of penetration of the spuds and of pressure of the wheels on the ground between them increase the tangential resistance; chains secured to the rims and spuds are means of increasing the drawbar pull, but the various types of spuds used on agricultural tractors show such differences of shape that it would appear improbable that the best form had yet been discovered. Probably a research conducted with some form of chain-track on which sets of spuds could be tried would provide useful data, because the conditions could be made more nearly constant in the chain-track on the wheel.

(*h*) *Auxiliary apparatus, such as pads or rings for use on the roads; a winch and scotches for step-by-step advance or for getting out of difficulty.*—The tractor designed for cross-country work is generally fitted with wide tyres, but, for running on the road, strakes are often used. Greater tractive effort and less damage to the roads can be obtained by means of rubber pads secured to the rim and projecting beyond the strakes or spuds. Another method is the use of detachable wheels with rubber tyres; a third arrangement consists of encircling rings that can be put over and secured to the spuds so as to enable conversion to be made rapidly to a smooth tyre without removal of the wheels or of the spuds from the wheels. For countries devoid of roads and bridges a winch and 100 to 150 yards of wire rope are essential for enabling the car itself or another of a convoy to be hauled out of trouble. It is necessary also to provide scotches, such as are shown in Fig. 7 for the reasons given under (*c*).

(*i*) *Crossing streams or flooded country.*—Frequently wide parts of a stream are to be found that can be forded, though the stones in the bed may give trouble. If, however, the convoy comprises two or more tractors fitted with winches, it is possible to send one ahead paying out cable and for it to haul itself or be hauled back if it should get into trouble. The displacement of water by the stones amounts virtually to a reduction in their specific gravity and thus increases the sinkage in flooded ground. It should be accepted that the tractor capable of conforming to the other conditions should also be able to cross water of a depth of 20 in., a depth which will enable much to be done in crossing flooded country. It is essential that speed can be maintained when running on the low gear without getting water into the ignition apparatus or the carburettor. It is also essential that the engine and gear-cases should be water-tight so that no damage may be done to the bearings, particularly if ball or roller bearings are fitted.

* See Proc. Inst. Mech.E. 1918, pages 56-77 and 144-5; Traction on Bad Roads or Land.



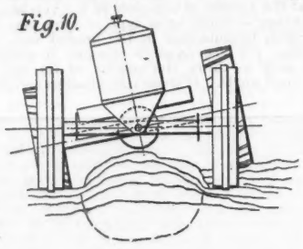
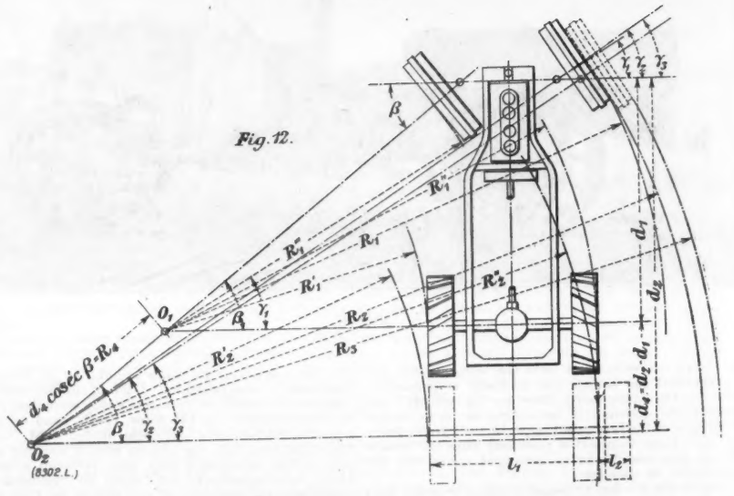


FIG. 11.

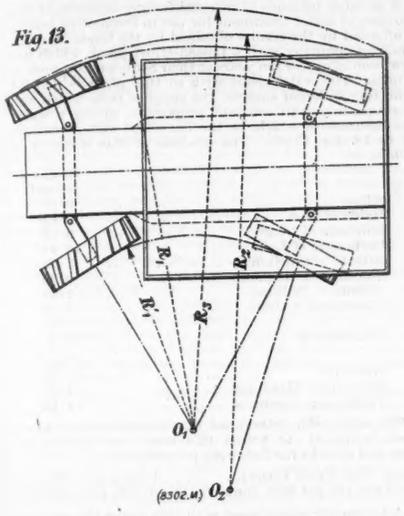


(*j*) *Ability to take hairpin bends on mountain roads.*—The zig-zags or hairpin bends that have to be taken in transport over mountain roads may have an overall width at the bend of 40 ft. or thereabouts, which necessitates a minimum turning radius of about 18 ft. measured over the extreme points of the body. The surface of the bends is moreover helicoidal, and this tends to throw the axles in winding particularly when the turning radius is very small and the gradients are steep.

The usual Ackermann steering generally allows a minimum angle of only 40 deg. for the inner steering wheel; to exceed this angle is to run risk of the steering becoming locked owing to the rod and lever coming into alinement. In order to keep the turning circle small the wheel-base must be short; any increase d_4 in the wheel-base (Fig. 12) involves an increase in the inner turning radius from R'_1 to R_2 that is an increase equal to d_4 cosec β. The increase is approximately the same for the outer front wheel. An increase l_2 in width of track of the wheels increases the outer front wheel radius by $l_2 \cos \gamma_2$ approximately. There is, however, a more important matter to consider and that is the track taken by the rear wheels which travel in a curve of much smaller radius than the front wheels, and cause a reduction in the clearance of the rear of the body on the inside of the curve; when the track is of the same width on front and on rear wheels $R''_1 = R_1 \cos \gamma_1$ approximately. For this reason, with front wheel steering the curves on hairpin bends should be taken as wide as possible. Four-wheel steering may be either symmetrical or asymmetrical (Fig. 13); in the latter case the inclination of the front and back wheels is unequal. In the case of symmetrical four-wheel steering the chassis width must be kept narrow because the same clearance is required for both front and rear wheels. A symmetric steering has two advantages: the change of position of the point of intersection of the axes of the wheels from O_1 to O_2

increases, it is true, the turning radius from R_1 to R_2, but it allows for greater width of chassis at the rear and keeps the rear of the body more nearly to the same circle as the front wheels, as shown by R_3. The ordinary position of the driver's seat considerably to the rear of the front wheels, is such as to cause the introduction of a new

Fig. 13.



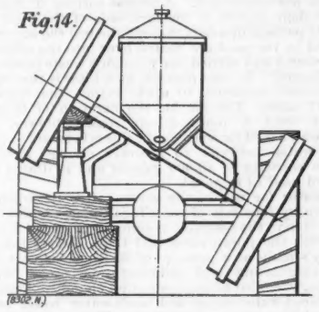
risk with four-wheel steering vehicles. The deviation of the rear of the front-wheel steered vehicle towards the inside is shown in Fig. 12, and if this is compared with Fig. 13 the risk of fouling stationary objects or other vehicles with the rear of a four-wheel steering vehicle may be seen to be considerably reduced by the asymmetric arrangement. The greatest disadvantage of four-wheel steering, however, is that which is found in town work, because a car drawn in near a kerb cannot be driven away either forwards or backwards except in a circle of large radius, and this radius can only be decreased when the vehicle has been moved through a length of about half the wheel base, the result being that much more space is required for manœuvring or much more room must be left between the vehicle and the kerb.

General Features of the Cross-country Tractor.

It is desirable that the tractor should be able to work with paraffin, particularly in hot countries, and that it be also arranged to run and to start with petrol. In the case of large power motors the impulse starter is an advantage. The motor should be of strong construction with cast-iron bed, and all valve-mechanism should be enclosed so as to protect the moving parts from dust and weather. In very dusty and sandy regions it will probably be found advisable also to filter the air before it is admitted to the carburettor. The carburettor and its supply must be capable of working when inclined at 45 deg. in any direction.

The maximum tractive effort to be provided at the wheels has been taken as equal to the weight of the tractor; if the first speed of the tractor is given (often between 0·8 and 1·5 miles per hour), then, taking the overall mechanical efficiency at 75 per cent., it is possible to determine the brake horse-power required to be developed by the engine. The next step is to decide the number of speeds and whether a single or double change is to be adopted; in any event it will probably be found advisable to adopt a range of speeds in geometrical progression. The sliding gear change has generally been fitted, but it has the disadvantage that in the case of very low speeds it is difficult to change to higher gear before the vehicle comes to rest. The epicyclic gear

Fig. 14.



would have advantages in this respect, but it presents difficulties of design, particularly as to ensuring the efficient lubrication of the pins on which the satellite gears rotate; this trouble has been overcome successfully in some well-known gear-boxes.

Four-wheel drive, according to English and American practice usually requires three differentials; though in France and Italy the third or intermediate differential is considered not only unecessary but actually harmful. The third differential in the English and American four-wheel drives comes into play when any one wheel loses adhesion, on ice or on a greasy patch; this wheel can then revolve at four times the normal speed, the vehicle remaining at rest. In order to prevent this it is necessary to fit one or more differential locks, which are somewhat brutal arrangements, or to adopt differentials of low mechanical efficiency, known in America as "automatic-locking differentials" of which there are many varieties. The Walter Superquad fits the Walter automatic locking differential on each axle and states that the third differential is unnecessary*).

The French and Italian practice, on the ground of unnecessary complication, dispenses with the intermediate differential; without it the ordinary differentials can be used on the two axles. The practical test for the fulfilment of the essential condition is that the vehicle should be able to start in either direction with one wheel lifted from the ground on a jack.

Any vehicle intended for cross-country traction should be subjected to the following tests: (1) With one wheel jacked up till the other wheel on the same axle leaves the ground the motor and all its controls should work as satisfactorily as on the level; the same should be the case with the clutch, gear-change, steering and both brakes (Fig. 14). (2) The same test should be met equally satisfactorily with the other axle similarly treated." (3) The vehicle should be lifted with a crane until the two wheels of one side are raised to the point of balance and the angle noted for obtaining the height of the centre of gravity. (4) The weights of the vehicle at rest on the front and the back axle, respectively, should be taken on the weighbridge (for obtaining the position of the centre of gravity). (5) The vehicle should stand being run through a water splash 18 in. deep at 10 miles an hour without causing trouble to ignition, electric gear or carburettor. In order to arrive at a solution that fulfils the requirements it is necessary for the designer to take advantage of suitable methods such as three-point suspension of the motor, radiator and gear box; proper provision of flexible joints in the transmission and special care in the arrangement of brake and steering details, it being born in mind that the main object is not to prevent the chassis from being thrown in winding, but to arrange that the parts will continue to work under these conditions. It is also desirable that the vehicle should be mounted on springs. (6) The vehicle should be run at slow speed up and down a slope at 45 deg. (or the maximum angle for which the tractor is designed) and turned on the slope in order to ascertain that the carburettor will function under all conditions.

If the various points mentioned are taken into due consideration it will be possible to avoid the errors that have resulted in the construction of many useless machines. The case of the machine propelled by feet will be first examined, because there are still inventors who hold the opinion that the evolution of the machine should follow the same lines that have been adopted by nature in the evolution of animals. A machine of German origin and recent construction shows the great difficulties that present themselves in this method of propulsion.

The wheel-less lorry (German).—This lorry (Figs. 15 to 19) has two pairs of feet each about 12 ft. 3 in. long by 6 in. wide, so that the total area of a pair is about 1,760 sq. in. The inner pair move together as also do the outer pair.

The method of driving is as follows: a cross-shaft is

Fig. 15.

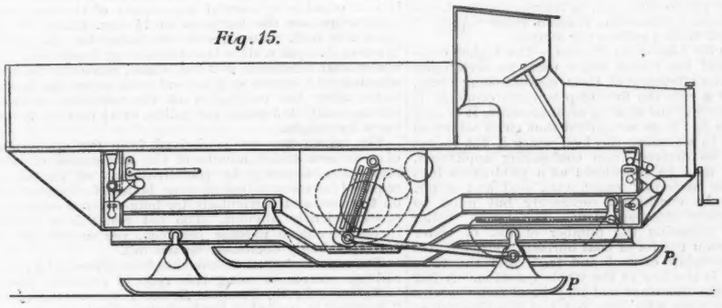


Fig. 16.

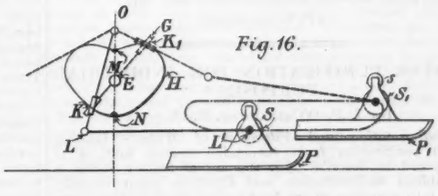


Fig. 17.

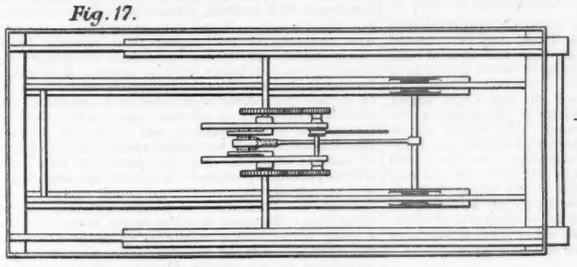


Fig. 18.

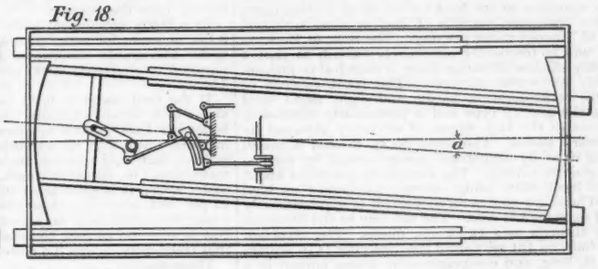
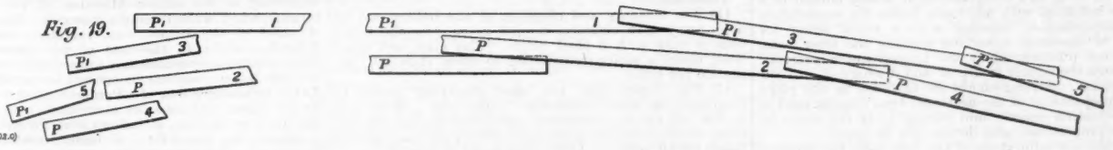


Fig. 19.



* The U.S. Government specification is quoted by one American maker as follows: "Differential; the differential shall be of such a type as automatically to permit the wheels to revolve at different speeds without complete loss of torque on either wheel, and also to apply at least normal torque to whichever wheel shall have traction. These requirements shall be met when the vehicle is running either forward or backward." See Proc. Inst. Mech.E., 1918, "Traction on bad roads or land," pages 62-3 and 137, *et seq.*

driven from the motor through a clutch and drives by means of spur gears the two co-axial shafts E E′, each of which carries an arm and slide-block controlled by a cam-plate HH′ so that the slide follows a definite path; this slide carries a second block so arranged as to give a variable stroke, and hence through the connecting rods the stroke of the feet may be varied from about 3 ft. down to 8 in. Each of the feet is fitted with a bracket, with carrying wheel on which the depressible rails can run and is also fitted with lifting rollers, which run on the lower flanges of the rails, so that the feet are lifted when the rails are raised. The rails are bent downwards over the central portion to clear the cam-gear and levers; each pair of rails is depressed and raised by a system of levers, and the rails are locked by toggle levers when in the lower position. The diagram (Fig. 16) shows the action of the drive and the path followed by the centre of the carrying wheel. The track of the centre of the inner feet is about 3 ft. 1 in., and that of the outer feet about 5 ft. 6 in. This difference is required for the steering arrangement, which greatly complicates the mechanism; the diagram (Fig. 18) shows how this is effected. A crank driven at the same speed as the cross-shafts drives a link-motion which communicates a variable to and fro movement to the bell-crank lever. If we consider the vehicle as making a step on the outer feet it moves in a straight line, but during this movement the inner rails and feet are swung through an angle corresponding to the setting of the steering gear and, when lowered, they take a position inclined in plan to the outer feet; then, while the movement of the vehicle takes place by the propulsion of the inner feet the action of the bellcrank causes it to swing about the centre of the carrying rails till the outer feet are again put down and commence a second straight line movement. During the movement on the inner feet the vehicle is consequently turned through twice the angle the feet make with its axis at the beginning of the step, and the turning is intermittent; a sharper turn can be obtained by shortening the stroke, or length of step of the feet, as shown in Fig. 18. The particulars of the actual vehicle are: load, 5 tons; loading area, 81 sq ft.; length of vehicle about 19 ft. 8 in.; width, 6 ft. 8 in.; height, 9 ft. 3 in.; height of platform, 4 ft. 3 in. ground clearance, 12 in.

It will be noted that the machine cannot accommodate itself to uneven ground, nor would the distribution of the load be equalized over the feet. Moreover, if the weight of the tractor itself is taken at 4 tons the pressure exerted on the ground would average over 11 lb. per sq. in. which is excessive for crossing snow or soft sand.

(To be continued.)

WATER PURIFICATION FOR INDUSTRIAL PURPOSES.*

By J. P. O'Callaghan, F.C.S.

Sedimentation and Filtration of Water.—Dealing with purification from suspended matter first, it is proposed to describe with the aid of lantern slides, a combined sedimentation and filtration plant recently put into operation at the Beckton works of the Gas Light and Coke Company, capable of dealing with 4,000,000 gallons of Thames water per day. The river at Beckton is tidal and is frequently excessively turbid, so that a thoroughly efficient filtration plant is essential to prepare the water for works purposes. The plant consists of four large sedimentation basins and eight rapid sand filters of the gravity type and is particularly interesting on account of the high degree of efficiency obtained by the primary basins. The water to be treated is raised from the river by centrifugal pumps driven by vertical spindle electric motors. The pumps are placed at about half-tide level, thus being entirely submerged at high tide, and having a maximum suction lift of approximately 14 ft. at extreme low tide. The delivery to the filtration plant is through two 12 in. c.i. mains. The filtration plant is built on 121 reinforced concrete piles 14 in. square and 38 ft. long, and comprises eight filters, housed in a suitable building, with adjoining basins for coagulation and sedimentation, together with a water tower for storage of cleansing water for washing the filter beds, air blower, pumping plant and filtered water reservoir, from which the supply is drawn and discharged into the works mains. Arrangements are included in the plant for the preparation of the necessary lime reagent used in the purification process and adding to it the water in suitable proportions, and details will be given.

The intimate admixture of the lime with the water is obtained by its fall into a trough and thence along distributing channels communicating with the coagulation and sedimentation tanks. These basins are of sufficient size to hold approximately 600,000 gallons of water, thus allowing for nearly four hours' time period for reaction and sedimentation when the plant is working at its full rated capacity. The design of the basins permits of speedy and efficient cleansing through the sludge valves and drain sewers. After allowing the heavier impurities and a considerable portion of the coagulated flocculent matter to be precipitated in the sedimentation basins the water is decanted over a trough communicating with the filter inlets.

The filter units, eight in number, are of the open gravity type. Each is 22 ft. long by 12 ft. wide, thus giving a total filtering area of 2,112 sq. ft. When the rated flow of 4,000,000 gallons per day is being dealt with and all the filters are working, each square foot of filtering area will pass 79 gallons of water per hour. The flow through the inlet valve of each filter passes along a system of communicating troughs placed above the surface of the sand bed, and the incoming water is thus distributed over the entire filtering area by overflowing the edges of these troughs. The filtering medium employed is a specially sifted and suitably graded mined quartz sand, supported on a bed of double-washed and graded gravel. Below this a manifold system of lateral collecting tubes fitted with safety strainers is arranged, which uniformly draws off the water from the entire filter-bed area. The filtered water thus collected is discharged through a central pipe and automatic rate of flow control valve into a chamber. From this it flows out through a weir into the filtered water channel, and thence to the reservoir sump of 60,000 gallons capacity, from whence it is picked up by high lift motor-driven centrifugal pumps and discharged to the works.

The filter beds are cleansed with air and wash-water. The operation is performed by agitating the filtering medium with air for about two minutes at a pressure of 3 to 5 lb. per square inch. A reverse current of cleansing water is then applied to the underside of the filter bed, and in its passage upwards through the bed the impurities deposited on the sand are floated over into the collecting waste troughs and carried out through a waste pipe to the drain channel. In this manner each filter is thoroughly cleansed and restarted to work within the space of 10 to 12 mins. The air for the aeration of filters is obtained from a motor-driven rotary blower. The filtered water used for washing the filters is raised from the filtered water reservoir to a tower storage reservoir, having a capacity of 40,000 gallons and is drawn from there and used as required.

The water for use in the works, after treatment, is picked up by four sets of centrifugal pumps which have their suction in the reservoir or sump constructed directly underneath the pump room and these deliver into the company's main at a pressure of 80 lb. per square inch.

The coagulating and sedimentation tanks, filters, platforms, chemical house, inspection chambers, channelling, filtered-water sump and wash-water tower are of reinforced concrete constructions. The plant is one of the largest ever put to work and, by its use, the Gas Light and Coke Company relieve the London water supply of over a thousand million gallons per annum.

Softening by the Lime-Soda Process.—The higher post-war cost of fuel has forced boiler users to investigate more closely the efficiency of their steam-raising plant, and, whilst as a rule the first step towards economy is taken by improving the stoking arrangements, it is now becoming more and more recognised that strict attention must be paid to softening the feed water if the fullest benefit is to be derived from coal-saving appliances. Steam raising may be considered as a production into which two raw materials enter, viz., coal and water. These cannot be considered separately but must be viewed as closely interdependent. The term "boiler evaporation" (meaning the number of lbs. of water turned into steam per lb. of coal burned), indicates this intimate relationship of fuel and feed, and the ratio between them is the key to the whole question. A few figures will make this clear and may be of some service to many boiler users who have not had the time to go closely into the matter.

In a fairly economical boiler plant an evaporation of 8 lbs. of water for every pound of coal may be expected under favourable conditions, so that the cost of coal required to evaporate 1,000 gallons of water amounts to 12*s.*

If the feed water is hard (say 20 deg. Clark scale), about 3 lb. of scale-forming matter is deposited in the boiler per 1,000 gallons evaporated. The cost of softening such water may be estimated at about 6*d.* per 1,000 gallons, including interest, depreciation, chemicals and attendance; or, in other words, 4 per cent. of the coal cost. When it is considered that a coal saving of 10 to 15 per cent. may often be effected by simply softening the water, the economical argument for softening is obvious. But in addition to this, there are other great advantages that frequently escape the notice of boiler users.

These are:—

(1) The cleaning and chipping of the boilers can be done away with entirely, beyond going over the boiler once a year with a steel brush. This may, and often does, mean a saving amounting to more than 30*l.* per annum per boiler.

(2) The boiler does not need emptying nearly so frequently as would otherwise be the case. With coal at 20*s.* per ton the monetary equivalent of the heat loss every time a boiler is emptied and started up again may be taken for an ordinary Lancashire boiler at over 5*l.*

(3) The life of the boiler is increased, and repairs cut down to the minimum. A Lancashire boiler costs, nowadays, about 1,200*l.* If by treating the water the life of such a boiler is prolonged for even a few years, that alone handsomely repays the outlay on a water softener.

(4) When economisers are in use their efficiency depends on the tubes being clean and free from heat-resisting scale. Great care is usually taken to keep the outside of the tubes scraped clean and free from deposit, whereas the inside (which is not seen) is often allowed to become almost solid with scale.

(5) In the case of turbines, when hard water is used even as "make-up" to surface condensate, it is a frequent experience that the lime and magnesia salts are carried over in the steam and settle on the blades, thereby reducing the efficiency considerably. A properly operated water softener prevents this loss of efficiency.

The outstanding feature of the Lassen-Hjort mixing and measuring apparatus is the device for the separate and exact measurement, in small, absolutely definite, and pre-determined quantities, which can be varied at will of both hard water and softening reagents. The lime-milk used in this apparatus has a strength of 10 per cent.; the lime-water used in earlier types of softeners had only an average strength of 0·13 per cent.; the lime-milk, therefore, has a strength of nearly 100 times that of the lime-water, and produces a far quicker and more complete reaction. A further advantage of using lime-milk is that a known quantity of fresh lime can be mixed with a known quantity of water, a solution being obtained, the strength of which is definite.

A striking instance of the satisfactory solution of the problem of water treatment for use in locomotive boilers is afforded by the results obtained by the Great Western Railway Company with a Lassen-Hjort plant, which has now been in use for ten years at their Swindon Locomotive Works. The water dealt with in this plant is derived from four different sources, the supplies from which are, however, mixed in constant proportion, giving a water the hardness of which, in the untreated state, averages 17 to 18 deg. Clark. The analysis of this water is as follows:—

	Grains per gal.
Silica	0·17
Oxide of Iron	0·13
Sulphate of Lime	0·68
Carbonate of Lime	15·41
Nitrate of Calcium	1·79
Sulphate of Magnesia	0·90
Nitrate of Sodium	2·63
Chloride of Sodium	1·64
Total Solids	23·35
	deg.
Hardness	17·75
Temporary Hardness	13·61
Permanent Hardness	4·14

The chemicals, determined by calculation and experiment, required to soften this water successfully are lime and soda in the following proportions:—

Lime (Nest Fresh Burnt)... ... 1·7 lb. per 1,000 gals.
Soda ash (58 per cent. pure alkali) 0·5 lb. per 1,000 gals.

A laboratory experiment with this water showed that it was possible by careful adjustment of the lime and soda to reduce the hardness to 1½ deg. Clark. Tests from the bulk water treatment taken by the Great Western Company, show that the average hardness of the water after treatment is 2 deg. Clark, while the residual alkalinity *i.e.* excess of lime and soda remaining in the water after the conclusion of the softening process) averages only 1·5 grains per gallon, or 1½ parts in 70,000 parts by weight.

The advantages to be derived from the application of a process which admits of the attainment of such remarkabe accuracy in the treatment of the water required for water tube stationary boilers, for locomotives on the line, and particularly for long-distance expresses, are sufficiently obvious. The net result is a largely increased engine mileage per loco. per annum and a correspondingly decreased repairs bill.

The experience just detailed has been repeated by other railway companies using this type of softening plant.

Softening by the Permutit Zeolite Process.—The name "Zeolite" is applied to the hydrated silicates of alumina combined with sodium, potassium, calcium, magnesium and other metals. These substances possess the remarkable property of exchanging their metallic bases for others under appropriate conditions of contact and of effecting the exchange in the reverse direction. For instance, a zeolite containing sodium as its base is able to replace the sodium with calcium if exposed to contact with a solution of a calcium salt. When the calcium zeolite has been formed it can be readily reconverted into the sodium salt by similar treatment with a solution of sodium chloride. By the power of base-exchange which Permutit possesses—both calcium and magnesium are completely removed from water which is passed through a "Permutit" or zeolite softener. All traces of hardness disappear and the water, when tested, gives a ready lather with a minimum quantity of soap. The softeners are without moving parts, the entire process consisting of the simple filtration of the hard water through a bed of the Permutit material. The installation of plant of the largest size, therefore, presents little difficulty, while, in the case of the natural Permutit lately adopted, depreciation is a practically negligible item and the labour required to operate is exceedingly small. As the softening power of a Permutit plant is drawn upon by the water itself in exact accordance with its hardness and its rate of flow, it follows that Permutit softening precludes the possibility of under-treatment or over-treatment. Variation in the quality and quantity of the water within the limits of the capacity of the plant make no difference, whereas in such cases of variation a lime-soda water softener would require frequent readjustment.

The Permutit system works equally well whether operated under pressure or by gravity and, in consequence, a softener can be fixed to the water service at any convenient level. This frequently saves double pumping, and allows of a practically unrestricted choice of position for the softening plant.

The base-exchange softening action continues until the active sodium in the Permutit molecule has been entirely replaced by calcium and magnesium. When this point has been reached regeneration is effected by passing a solution of sodium chloride slowly through the filter; by this means the calcium and magnesium, as soluble chlorides, are expelled from the Permutit, their place being taken by sodium from the salt solution, thus reconstituting the original sodium Permutit, which is then as fresh and active as when first put to work. The alternating cycle of softening and regeneration is capable of indefinite prolongation.

Another type of Permutit has recently been introduced for industrial use. This new material, named "Permutit B," differs from ordinary Permutit both in physical characteristics and molecular constitution, these differ-

* Paper read before a Joint Meeting of the Institution of Mechanical Engineers and the Chemical Engineering Group of the Society of Chemical Industry on Tuesday, February 26, 1924. Abridged.

ences causing a radical change in the timing of the periodic cycle of softening and regeneration, enabling day and night continuous duty to be performed by one unit only instead of two. In the case of ordinary Permutit a single unit was usually designed to soften continuously for a maximum period of 10 or 12 hours, and it then required an equal length of time for regeneration. Therefore, day and night working involved employment of two units. In the case of Permutit B the plant is designed to operate for periods varying from three to six hours at a time, and is then competely exhausted. The material, however, is capable of extremely rapid regeneration, and a large industrial unit can be completely regenerated and recommissioned in an hour.

Although the actual base-exchange activity of the new material is somewhat less than that of the ordinary Permutit, this is amply compensated for by the more rapid action of the material in both directions, i.e., during softening and regeneration. By taking advantage of this, a higher rate of flow during softening can be obtained, while the reduction of the period of regeneration from 12 hours to one hour has become ordinary practice. The introduction of the new material has very sensibly advanced the base-exchange process in the direction of continuous operation, and made possible a considerable saving in first cost, one unit only being required. A most important advantage was that a reduced salt consumption in regeneration was possible with Permutit B as compared with the older material. Again, the new material is of a hardier physical character and, therefore, less susceptible to loss through wear and tear in general usage.

In many respects softening boiler feed water by means of zeolite offers great attractions. The method is not applicable, however, to every case, and careful preliminary investigation should always be made of the quality of the raw water supply, the operating conditions of the boilers and the service to be rendered. The question can only be satisfactorily decided in the light of a reliable analysis of each water, due regard being paid to the proportions of temporary and permanent hardness, the boiler pressure, type of boiler, &c.

At several places combined lime-soda and Permutit systems have been installed and are operating satisfactorily. It is not usually economical to treat a water entirely by the regenerative process where the hardness of the water is in excess of 40 grains per gallon and in such cases a combined plant can be effectively employed. The Permutit process removes all the hardness produced by calcium and magnesium salts, and can, by modification, be used to remove all iron, manganese and organic matter which the water may contain. Wool washed with zero water is freed entirely from lime, while if washed with water of only 3 deg. hardness, it will contain an appreciable amount. The impairment of wool by its lime contents and the difficulty it causes the dyer are only too well known. Experience shows that for each degree of hardness about 1¼ lb. of soap are destroyed by 1,000 gallons of water treated. The soap loss is the bugbear of manufacturers and, moreover, is unavoidable, as the softening process completes itself with any soap that may be used before any benefit, such as is expected in the process of manufacture, can accrue.

When silk is treated with soap in the process of manufacture, it is impossible to wash the soap completely from the skein on account of the formation of insoluble calcium and magnesium compounds. Moreover, in the subsequent weighting the tin does not adhere uniformly to the soil owing to the lime and magnesium soap precipitates that have formed. The weighting is thus rendered very irregular. The disadvantages which result from the formation of these precipitates in the baths are well known to manufacturers and dyers. The important part which completely softened water plays in this branch of industry can therefore easily be realised.

The great success of the French silk industry is mostly due to the purity of the water used, a fact acknowledged by the manufacturers themselves. Nevertheless, the largest of the French silk houses has installed the Permutit process to remove the small degree (about 5 deg.) of hardness in the water.

In several manufacturing processes it is desirable that the water used should be absolutely free from both iron and manganese, and, when these are present only in very minute quantities, it is almost impossible to remove them entirely by any of the older processes. A modification of the Permutit process makes this removal possible. By treating sodium permutit with a manganese salt, a manganese permutit is produced, and, upon passing water through a layer of this arranged in an apparatus similar to that used to remove hardness, all the iron and manganese salts are oxidised and precipitated. This is not a lime exchange action but an oxidising process. At the same time, all organic matter and any bacteria which may be present are also oxidised, the manganese permutit being periodically regenerated by the addition of solution of permanganate of potash. The process is very simple and thoroughly effective, costing for regeneration less than ¼*d.* per 1,000 gallons.

AWARD TO AUSTRALIAN METALLURGISTS.—The Gold Medal of the Institution of Mining and Metallurgy (the premier distinction within the gift of the institution) has been awarded conjointly to Herbert William Gepp, M.Inst.M.M., and Gilbert Rigg, M.Inst.M.M., in recognition of their joint and individual services in the advancement of metallurgical science and practice, with special reference to their achievements in the treatment of complex sulphide ores, and in the development of the electrolytic process for the production of zinc in the Commonwealth of Australia.

WATER-SOFTENING BY MEANS OF DOUCIL.*

BY T. P. HILDITCH and H. J. WHEATON.

THE softening of water by passage through a bed of base-exchanging material has become so familiar a process that it is only necessary to point out that lime and magnesia in hard water are exchanged for the equivalent of soda, and that the spent material is regenerated by passage of brine through it. Hence the operating costs are the salt required, together with water (for solution of the salt and for washing the spent brine out of the filter and occasionally for flushing the filter) and the small amount of labour necessary to carry out this operation.

The chief characteristics of the softened water produced by this method are that it can be adjusted to any desired degree of hardness from complete softening or "zero hardness" upwards, and that it contains all the salts originally present in the water, except that salts of calcium and magnesium are converted into salts of sodium.

For different waters and purposes either the base-exchange method or the lime-soda precipitation method may be the more suitable—the latter removes most of the dissolved calcium and magnesium carbonates and converts the other salts to the corresponding soda salts, but cannot reduce the hardness in practice to much below 2½ parts of lime per 100,000 of water. For many purposes it is held necessary to employ completely softened water, and even where this is not imperative the base-exchange process has frequently much to commend it in its simplicity of manipulation, whilst the cost of salt for regeneration compares very favourably nowadays with that of the chemicals used in the lime-soda process.

The present note is concerned with a description of a comparatively new base-exchange material manufactured by Messrs. J. Crosfield and Sons, Limited, of Warrington, under the name of Doucil. The oldest base-exchanging compounds on the market, the natural zeolites, consist of rounded granules of no great degree of porosity, and it is evident that all the softening action takes place very close to the external bounding surface of the grain. Indeed, chemical analysis shows that but a small proportion of the soda-content of a natural zeolite is available in water-softening. Messrs. Crosfields have been compelled to pay careful attention to the phenomena of surface action for a considerable period in quite other directions, and consideration of the experience thus gained indicated that if suitable porosity and surface could be secured it should be feasible to produce a base-exchanging compound in which much more of the combined soda could be utilised to produce soft water than in the cases of previous materials, natural or artificial. This expectation was realised when it was discovered how to produce a complex silicate containing replaceable combined soda in the form of a dried gel.

The first type of doucil gel made (English Patent 142,974) was simply a very acid sodium silicate, made by the interaction of dilute solutions of sodium silicate and a mineral acid, or preferably of an acid salt, of which sodium bicarbonate is one of the most convenient to use. These products, however, do not contain more than about 3 per cent. of combined sodium oxide, and not much more than one-third of this is available for base-exchange, the remainer being apparently converted into a calcium silicate.

The chemical interaction underlying the formation of the gel is rather interesting: with acid salts it is simply, of course, a case of withdrawal of soda from the silicate by the stronger acid, but it is curious to find that neutral salts of complex acids such as dichromates, pyroborates or metaphosphates show the same action, neutral salts of less complex acid being produced. With dichromates the action is easy to follow by the colour-change from orange to pale yellow, which occurs before gelatinisation sets in. For example,

$$(Na_2O(SiO_2)_3)_n + (n-1)Na_2Cr_2O_7 = 2(n-1)Na_2CrO_4 + Na_2O(SiO_2)_{3n}.$$

A similar process takes place when a dilute solution of ordinary sodium silicate, containing 2 to 4 molecules of silica to one of soda, is mixed with dilute sodium aluminate solution; silica is a stronger acid than aluminium oxide, and sodium oxide is withdrawn from the aluminate with production of sodium meta-silicate. The residual components enter into combination as a sodium alumino-silicate which is produced in the form of a gel (English Patent 177,746).

The final dried and washed product conforms closely to the anhydrous composition Na_2O, Al_2O_3, $(SiO_2)_5$, which demands 13·3 per cent. Na_2O, 22·0 per cent. Al_2O_3 and 64·7 per cent. SiO_2. Of the soda present, rather more than 3 per cent. is converted into non-exchangeable calcium silicate, and the remaining 10 per cent. can be completely replaced alternately by lime and by soda. Of course, this complete replacement cannot be effected with simultaneous production of completely softened water, since this would require that the material should be as permeable to water as water itself, or that the granules should continue the base-exchange equilibrium internally as rapidly as the exterior surface action between the water and the parts of the doucil surface to which it has free access.

As a matter of fact an internal establishment of base-exchange equilibrium does proceed with the particles, but it is relatively slow compared with the exterior surface action. This is proved by the fact that a partially spent bed of doucil, if left for a few hours, is then able to soften water distinctly better than when the flow of water was previously interrupted. For practical purposes, however, and especially if completely softened water is required, about 40 per cent. of the exchangeable soda, or 4 per cent. of the weight of anhydrous doucil present, is exchangeable for lime before the doucil allows appreciable quantities of calcium or magnesium salts to escape.

Doucil is marketed on a 50 per cent. moisture basis, so this is equivalent to saying that a ton of doucil will soften to "zero hardness" about 22,000 gallons of water, containing 20 parts of lime per 100,000 (or 25 grains of calcium carbonate per gallon.) (For base-exchange work it is convenient to base the hardness on lime rather than calcium carbonate; also, with doucil, any magnesia present is calculated to its chemical equivalent of lime.) To obtain a base-exchange capacity of this high order, two factors are necessary:—

(*a*) The doucil must be properly prepared.

(*b*) It must be used in a plant so designed that all the material is evenly exposed to the flow of water; if the arrangement is such that the water can take a line of least resistance, plainly the doucil along that path will have to do all the work. The correct preparation of the material is the responsibility of the manufacturer; its correct use depends upon the firm which erects the containing plant.

It may be of interest to give a few particulars of each side of the question—production and application. In addition to maintaining the activity or base-exchanging capacity of doucil at its maximum it is desired to produce it in as hard a form as possible, and in grains of a size which combine maximum accessibility of water with as little resistance as possible to the flow of the latter.

The early stages of manufacture are all-important in securing both high activity and hardness of grain; the generating solutions must be so mixed that the whole sets to a perfectly homogeneous mass of gel. This is controlled by careful adjustment of the concentrations of the aluminate and silicate solutions, and of their respective soda contents, and by suitable mixing devices. If clots of gelatinous precipitate or merely portions of different degrees of opacity (connoting variation in composition) appear in the gel mass, the hardness of the final product will suffer and in the factory such products, when accidentally encountered, are rejected.

The fresh gel is transferred without disturbance to a drier, in which it remains for four or five days whilst its water-content, originally about 90 per cent., is reduced to about 50 per cent. Too rapid drying, and especially drying at more than a very moderately elevated temperature, injures the final product. The dried gel is quite hard, and of a somewhat horny appearance, and is generally obtained by shrinkage during drying in the form of lumps about 2 in. in diameter. These are washed in a slow stream of distilled water for some hours, during which the enmeshed sodium metasilicate, &c., is dissolved away, leaving the doucil in whitish lumps, which are submitted to further drying for about a day. This second drying assists to harden the material, and also renders it more easy to break down into grains of the desired size. The production of the latter is now a purely mechanical problem.

At first the manufacturers were unduly afraid of the resistance to water flow and recommended the use of relatively large grains, at least in the lower part of the doucil bed. It was soon found, however, that softening capacity was being wasted in this way, and that the material was sufficiently hard not to pack down too tightly under water pressure when used in a smaller grade.

The preferred size is now from ⅛ in. to $\frac{1}{10}$ in., whilst a still smaller size, $\frac{1}{20}$ in. to $\frac{3}{10}$ in., is sufficiently granular to be very useful as a top layer in a doucil filter. A bed 6 ft. deep of the former size offers a resistance to water-flow of only about 1 lb. per square inch at normal rates of flow, whilst a 3 ft. bed of the smaller grade has a resistance of about 4 lb. per square inch under similar conditions. Comparative measurements of resistance to disintegration by agitation under water have shown that the ⅛ in. to $\frac{1}{10}$ in. grains of doucil lie between similar sized fragments of sandstone and of marble in this respect.

It may be remarked that the doucil is graded by passage through circular holes of the diameters given, and that in breaking down it splinters rather than crushes, so that the length of many of the doucil grains is greater than the upper limit of ⅛ in. Given suitable pipe arrangements for securing an even flow of water into and out of a doucil container over the whole of its cross-sectional area, no supporting bed of gravel or other inert material is necessary, and the doucil is simply charged into the container and, when the cover has been fitted, is washed upwards with water in order to settle the bed evenly. It is worth repeating once again that it is of the utmost importance to ensure a perfectly even flow of water through the bed. The depth of bed is largely a matter of convenience, but it is definitely proved that a deeper bed gives disproportionately better results, a 6 ft. bed, for example, softening about 15–20 per cent. more water than two 3 ft. beds of the same area.

Some indication has already been given of the water-softening capacity of doucil, and it only remains to be added that the capacity is naturally diminished if excessive amounts of sodium salts are present in the raw water, as these tend to reverse the base-exchange equilbrium. The salt consumption is much reduced by using the last portion of the brine from one regeneration as the first half of the brine from the next regeneration (English Patent No. 203,497); in this way the consumption is about 8 lb. of salt per 1,000 gallons of completely softened water of an original hardness of 20 parts of calcium oxide per 100,000. The amount of water used in solution of salt (5 per cent. brine) washing and occasional back-flushing does not exceed 4 per cent. or 5 per cent. of the water softened. The partially-spent and fresh

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* Paper read before a Joint Meeting of the Institution of Mechanical Engineers and the Chemical Engineering Group of the Society of Chemical Industry on Tuesday, February 26, 1924.

brine should each occupy about 20 to 30 minutes in passage through the doucil bed, after which washing is carried out as rapidly as possible and need not exceed 15–20 minutes. The plant may be designed so as to be regenerated daily; weekly or at any suitable intervals.

The simplest way to operate a doucil plant is to pass the hard water downwards; regeneration should take place in the direction of upward flow, to minimise mixing of brine and water as far as possible, whilst displacement of the last portions of brine to a store-tank and subsequent washing are conducted in a downward direction.

A cubic foot of plant space contains about 35 lb. of doucil (50 per cent. moisture); thus to soften the 22,000 gallons of water previously referred to a plant capacity of about 64 cub. ft. is necessary, *e.g.*, a doucil bed 6 ft. deep in a cylindrical shell about 3 ft. 6 in. diam. by 8 ft. high would be suitable, with a brine tank capable of holding about 360 gallons of liquor.

Just as much as in the case of a catalyst, it is important to preserve the surface of the doucil grains in an absolutely clean condition, and therefore only water free from suspended matter should be admitted to the doucil bed. Suspended matter, especially if colloidal in nature, will tend to adhere to the active surface, and should be removed by prior passage through a mechanical filter. Similarly, any chemicals present in the water which might produce a precipitate at the surface of the doucil render such water unsuitable for treatment by doucil.

For all ordinary or average waters, however, the doucil method of softening is readily applicable, and the following types of water-supply may be given as indications of its use:—

(i) Ordinary domestic supplies;

(ii) Supplies to laundries;

(iii) Supplies to dyeing, bleaching and other textile works (doucil-softened water is completely free from alkalinity after the material has been regenerated for the first time);

(iv) Boiler feed water, at all events for steam-pressures up to 120 lb. per square inch (the base-exchange method is apt at present to give difficulties with corrosion on high-pressure boilers; it is hoped later to devise methods which will eliminate this risk).

Low-Powered Flying.—In a paper read before the Institution of Aeronautical Engineers on Friday, the 22nd inst., Mr. W. O. Manning, the designer of the "Wren" light aeroplane, which put up such an excellent performance in the course of the Lympne trials last autumn, gave an interesting account of the considerations underlying the design of the machine and applicable to low-powered aeroplanes in general. He referred, in the course of his remarks to an important characteristic of these machines, which probably arises from the high degree of lateral damping, viz., that they show no tendency to put one wing down suddenly when stalled. Certain low-powered machines, including the "Wren," Mr. Manning stated, had been stalled repeatedly without any untoward occurrence. This is obviously a distinct advantage from the point of view of safety. Another point referred to was the excessive weight of instruments, the author stating that the speed indicator fitted on the "Wren" was slightly heavier than the engine mounting. He suggested that much lighter instruments could and should be provided, calling attention to the fact that ordinary aeroplanes would benefit from the weight reduction as well as low-powered machines. We illustrated and described the design and construction of the "Wren" light aeroplane in our issue of October 26 last on page 526.

Workmen's Compensation.—The subject of workmen's compensation seems to appeal to different people in different ways. The lawyer is inclined to be more interested in fine questions as to whether in given circumstances a workman is entitled to compensation than in questions as to the amount of the compensation. The insurance expert seems, as a rule, more interested in questions of amount. The employer and the worker are presumably equally interested in both aspects of the matter. Mr. William A. Hurst, of the Car and General Insurance Corporation, Limited, in a lecture on the Workmen's Compensation Act, 1923, delivered in the hall of the Institution of Mechanical Engineers on February 21, under the auspices of the National "Safety-First" Association, appeared, as might have been expected, to be more interested in questions of amount than in questions of procedure or in the new factory legislation as to the notification of accidents, which is incorporated in the new Workmen's Compensation Act. Doubtless it would be difficult to lecture on an Act such as this in general terms, but Mr. Hurst attempted little more than a brief summary of the leading provisions of the Act. In the discussion which followed reference was made to the new requirement that accidents in factories which disable the injured person for more than three days from earning full wages at the work at which he was employed are to be notified in writing to the factory inspector of the district. A well-known member of the factory department who happened to be present at the lecture deprecated Mr. Hurst's suggestion that every accident, however trivial, should be reported to the factory inspector. He indicated that the increase in the notification of accidents which had resulted from the passing of the new Act had increased the clerical work in the factory inspectors' offices and that the factory inspectors did not wish to be "snowed-up" with reports of every kind of trivial accident, sent in by employers without regard to whether they were notifiable or not. The lecturer and those who took part in the discussion were liberally complimented by the chairman of the meeting, Lieut.-Colonel G. H. Bowden, M.I.Mech.E.

PHYSICAL SOCIETY OF LONDON.

An ordinary meeting followed the annual general meeting at the Imperial College of Science, South Kensington, Mr. F. E. Smith, C.B.E., F.R.S., the newly-elected president, was in the Chair.

Æolian Tones.

A paper on "*Æolian Tones*" was read by E. G. Richardson, M.Sc., East London College. The paper was illustrated by demonstrations. The history and previous scientific work concerning vibrations maintained by fluid motion was first described. New experiments for testing, by several methods, the dependence of the pitch n on the fluid speed V, and on the diameter D, of the vibrator in a number of fluids followed. The results showed V/nD to fall from 8 to 5, while D ranged from 0·02 to 2 cm., whatever the viscosity. Results for square-section cords were also given, and a value of the critical speed for turbulence deduced.

Dr. F. Ll. Hopwood congratulated the author on the quantitative results obtained in the face of great experimental difficulties. He referred to the author's conclusion that the pitch of æolian tones is not greatly affected by changes in the viscosity of the fluid. In repeating some of the experiments of Lord Rayleigh and Strouhal he had found that the pitch varies with temperature in a way that might be connected with changes of viscosity due to temperature. The author's suggestion that the sound came from the wire and not directly from the vortices was not confirmed by an experiment of his own in which a gas-supplied tube, perforated to give luminous jets, was rotated about a parallel axis in place of Strouhal's wire. In this case the occurrence of the critical or turbulent state could easily be observed by watching the gas jets, and the change of tone on reaching this state was very marked; while the tube itself was too stiff to emit audible sounds in the circumstances.

Dr. W. S. Tucker said that if a wire be heated by an electric current so as to form a hot-wire microphone, connected through an amplifier to a receiver, and rotated, a musical note is produced in the receiver at certain speeds, in consequence of the effect of the transverse vibrations of the wire in causing variation of convectional heat-losses. At the critical velocity the musical note breaks down into a crackle. If the resistance of the wire be plotted against its speed relative to the air, a regular curve is obtained until the critical velocity is reached; thereafter the relation becomes irregular and unstable.

Dr. C. V. Drysdale added his congratulations on the author's success in a difficult research. The absence of the fundamental from the series of tones appeared to suggest that the phenomenon was akin to that of the oscillating thermionic valve, in which the oscillation depended on the departure of the characteristic from the linear law. The resistance of a fluid to motion was nearly linear at low velocities, but became practically parabolic as the speed increased, so that it was reasonable to expect that oscillations would not commence until the speed exceeded the limit of the linear law, and this appeared to be confirmed by the connection between oscillation and turbulence. If the force on the wire could be measured at different speeds, it would probably throw a good deal of light on the theory.

While appreciating the difficulty of making satisfactory photographic records of the vortices, he suggested that if the author were to employ a convergent beam of light focussed on the diaphragm of the photographic lens but just outside its aperture, a dark field would be obtained in which the smallest curvature of the surface would appear as a bright area; and he thought that in this manner very clear photographs of the vortices might be obtained.

Mr. A. H. Davis suggested that the quantity V/nD should be plotted against the non-dimensional quantity VD/ν, instead of against D, as above. As it is, three different curves are obtained for water, air and viscous liquids, whereas (unless some factor has been left out of account) by plotting non-dimensional quantities identical curves should be obtained. Dimensional considerations show that the quantities V, n D and ν cannot be arranged in an equation in any way not reducable to Lord Rayleigh's form $V/nD = f(VD/\nu)$. If, therefore, one curve drawn to such co-ordinates did not serve for all cases, it would follow that some factor additional to those considered by the author must be taken into account. The speaker had tried plotting some of the results given in the paper in the manner described, and the agreement for different fluids was fairly good, except, perhaps, in the case of water. On the other hand, he said, Relf's results for water agree fairly well with the author's results for air and viscous mixtures. It seemed important to use non-dimensional quantities for both co-ordinates in order to bring out as fully as possible the theoretical bearing of the results. The vortices described in the paper appeared to be of interest in connection with the stresses experienced by wires in an air stream. In studying these it is usual to plot a non-dimensional force factor against VD/ν, but it seems possible that some property not accounted for is responsible for certain irregularities (Bur. Stds. Sci. Paper 394).

Mr. F. E. Smith said that the paper described a number of very difficult experiments. He pointed out that there seemed to be no justification for drawing part of the curves in Fig. 3 horizontal. The author's reply will appear in the Proceedings.

The Effect of Torsion on the Conductivities of Metals.

A paper on "*The Effect of Torsion on the Thermal and Electrical Conductivities of Metals*," was read by J. E. Calthrop, B.A., B.Sc., East London College. A method which had been described previously and used for the determination of the changes in the thermal conductivities of metal wires, was used for brass, iron, zinc, nickel and tin. As in the earlier experiments, the small decreases obtained on twisting were proportional to the square of the twist, as was approximately the case for the electrical conductivities. Iron had been most closely studied. It appeared to require several days to return to its original value of the thermal conductivity after the twist had been removed, and if the twist was kept constant there was a slight return towards the initial value.

Professor A. O. Rankine inquired whether any answer could now be given to the question which he had put on a previous occasion—viz., whether the change of conductivity depends in any way on the sense or direction of the twist. He also inquired whether the stress had been carried up to the elastic limit, and pointed out that the fatigue of the specimens was bound up with their crystalline structure. It had recently been stated that it is possible to make crystals of tungsten a quarter of a mile long; by working with a single crystal it might be possible to obtain further information.

Mr. F. E. Smith added that Professor Carpenter had made crystals of aluminium several inches long, and suggested that the author might relate his results to the changes in length and cross-section of the wire under torsion.

Dr. T. Barratt (communicated). The author does not commit himself to any theory to explain the changes in thermal and electrical conductivities when the wire is twisted. It would appear possible that a change in the sectional area of the wire on twisting might of itself produce changes of the order found experimentally. But a more probable cause is to be expected in the re-arrangement of the metallic crystals of the wire. In a drawn wire these crystals would lie mainly with their longer ones along the length of the wire. On twisting the wire the crystals would tend to be displaced in such a way that the current (thermal or electric) would flow through them more or less diagonally. The effect would then correspond to the differences of conductivity found in a crystal in different directions. A similar theory might explain Johnstone's* result that the thermal conductivity of a metal increases slightly when the metal rod is stretched along its length. In this case the effect of stretching would be to place more of the crystals with their longer—and presumably better conducting—axes along the length of the wire, and thus increase its thermal conductivity. The theory might possibly be tested by experiments on wires of similar material, some of which possessed a more marked crystalline structure (by annealing, for example) than others. The former should then give greater changes in conductivity than the latter.

The author's reply will appear in the Proceedings.

Microscope for Observation of Interference Fringes.

A Demonstration of "*Microscope for Observation of Interference Fringes*," was given by C. W. Hawksley. In examining the interference rings seen in a crystal by means of convergent polarised light it is common to use an additional optical system called a Becké lens placed over the eye-piece for the purpose of increasing the size of the image without impairing its definition. In a new arrangement forming the subject of the Demonstration the additional optical system consists of four lenses disposed as in the upper draw tube of an ordinary field telescope—viz., an erector and a Huyghens eye-piece. The image is thereby much increased in size without appreciable loss of definition, and this result may be still better effected by removing the eye lens of the microscope eye-piece. For optimum definition it is better to locate the analyser over the eye-piece of the telescope system rather than between the eye-piece and the objective. Two microscopes were shown having 1/6-in. objectives and No. 2 eye-pieces, and fitted respectively with the two systems referred to. The advantage of the new system was very marked. For monochromatic illumination use was made of the forked stems employed for supporting incandescent gas mantles. These when impregnated with sodium carbonate and raised to incandescence afford a convenient and durable source of illumination.

British Coasting Shipping.—Bearing the title "British Coasters, 1924," the first edition of a new annual publication giving particulars of steamers and motor vessels ranging from 100 to 1,000 gross tons, and engaged in the British coasting trade, has just been issued by Messrs. Sampson, Low, Marston and Co., Limited, 100, Southwark-street, S.E. 1. The work, which has been compiled by Messrs. F. J. N. Wedge and F. C. Bowen, is a companion volume to the authors' "Merchant Ships of the World," which deals with ships of 1,000 gross tons and over, and was noticed on page 647 of our 115th volume. In "British Coasters," the vessels are arranged under the owners' names and the data given includes the tonnages, speed, draught-length, &c., as well as particulars of machinery, hatches and cargo-handling appliances. Sea-going tugs and salvage craft are also included in the list, as well as cargo vessels, and this feature will doubtless be appreciated by all who have occasion to make use of the services of these vessels. The volume, which is strongly bound, and clearly printed on stout paper, contains indexes to the names of the vessels arranged in alphabetical order, and also arranged according to deadweight tonnage and horse-power. Its price is one guinea net.

* Proc. Phys. Soc., vol. 29, page 195 (1917).

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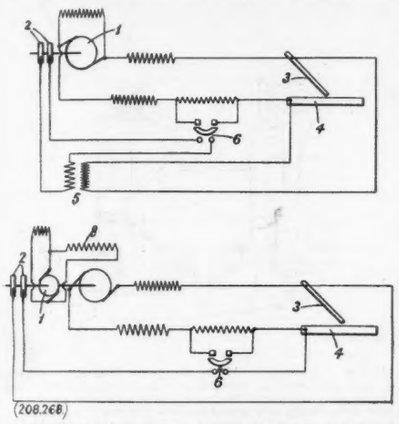
ELECTRICAL APPARATUS.

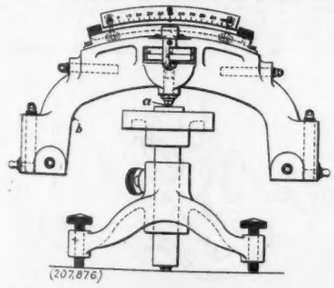
208,268. J. H. St. H. Mawdsley, Barnwood, Gloucester. Dynamo-Electric Generators. (2 *Figs.*) September 29, 1922.—The invention has for its object to provide a dynamo-electric generator for electric welding. Electric welding apparatus, in accordance with the invention, comprises a dynamo-electric generator to generate both direct and alternating current,



and having both a commutator 1 and slip rings 2, with the commutator 1 connected either to the electrodes 3, 4 or to a field winding 8 of a second generator to supply current to the electrodes 3, 4 and the slip rings 2 connected either directly or through a transformer 5 to the electrodes and switch means 6 to cut off the supply of alternating current to the electrodes when the arc has been struck. (*Accepted December* 28, 1923.)

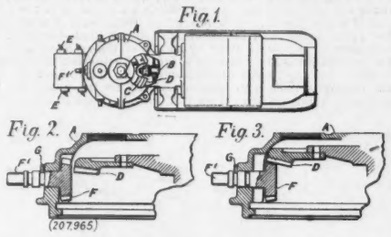
MINING, METALLURGY AND METAL WORKING.

207,876. E. G. Herbert, Levenshulme, Manchester. Testing the Hardness of Metals. (10 *Figs.*) September 7, 1922.—According to the invention, the hardness of a metal is determined by rolling or oscillating a weighted test member upon the surface of the metal and by measuring the free angular movements of the test member in respect to "amplitude" and/or "time," the invention being based upon the fact that the angular movements of a weighted rolling or swinging test member of hard substance upon the metal to be tested are definitely related to the hardness of such material, both in respect to "amplitude" and "time." The means for conveniently carrying out the invention comprise a swinging gravitational weight member or compound pendulum *b*, and a spherical or cylindrical test member *a* attached to and supporting the weight member of pendulum *b*.



The test member is composed of a hard material, such as sapphire or hardened steel. The weight member or pendulum *b* will usually be in the form of a metal bar with downwardly extending extremities and with the test member arranged centrally below the bar, means being provided to balance the bar by shifting its centre of gravity in each of its three principal axes, and means also being provided whereby the centre of gravity of the pendulum can be accurately adjusted to coincide with the centre of curvature of the test member, so that when the latter is placed upon a smooth hard horizontal surface the test member will be in neutral equilibrium, *i.e.*, without any tendency to roll, and will support and maintain the pendulum with its axes in any position in which they may be placed, said means also enabling the centre of gravity of the bar to be lowered or raised by a predetermined amount. (*Accepted December* 19, 1923.)

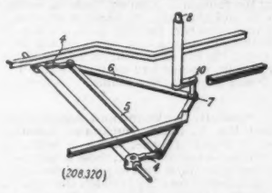
207,965. Mayor and Coulson, Limited, Glasgow, and A. W. Davies, Glasgow. Coal Cutting Machines. (4 *Figs.*) November 1, 1922.—The invention refers to cutter chain machines for use in mining coal. A is the head casing of the machine, B the motor-driven shaft, C the motor-driven pinion fixed on the shaft B, D the first gear wheel of the gearing, E the cutter chain and F the auxiliary pinion. The auxiliary pinion F is fixed on a shaft F1 mounted in a bearing extending through the side of the casing A and located at a position such that its axis is radial to the axis of the first gear wheel D, being (see Fig. 2) incapable of meshing when the first gear wheel D is in mesh with the motor driven pinion C, and (see Fig. 3), at a position for gearing when the first gear wheel D, after being moved



axially, is taken out of mesh with the pinion C. The shaft F1 is capable of endwise movement and is provided with means for retaining it in either of two positions. For retaining the auxiliary pinion F in these positions a latch G is provided having a jaw to engage with either of two circumferential recesses formed in the portion of the shaft which projects from the outside of the head casing. (*Accepted December* 19, 1923.)

MOTOR ROAD VEHICLES.

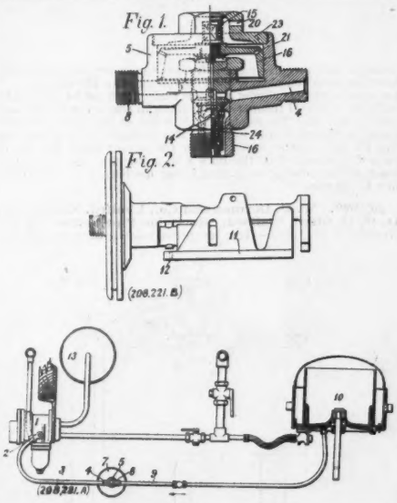
208,320. G. F. Melen, Birmingham, and H. C. Melen, Birmingham. Steering Mechanism. (2 *Figs.*) November 4, 1922.—The invention has relation to the steering mechanism of the front pair of wheels of a three-wheeled carrier vehicle. According to the invention, the tie rod 5 uniting the pivotal wheel axle arms 4 forms one side of a triangulated construction



involved by further tie bars 6, the apex 7 of which is moved in a curved path by a rotatable steering shaft 8 having an offset part 10 which is attached to such apex. In this manner the entire triangulated construction is adapted to be moved laterally to one side or the other of its central position, so that the wheels of the vehicle move through a segmental path, and always remains in parallel relation. (*Accepted December* 28, 1923.)

RAILWAYS AND TRAMWAYS.

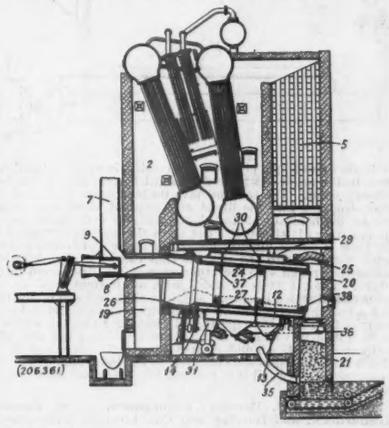
208,221. R. T. Glascodine, Westminster, London, W. F. McDermid, South Woodford, and A. Spencer, Westminster, London. Brake Systems and Apparatus. (9 *Figs.*) September 13, 1922.—The invention relates to brake systems and apparatus in which the brakes are applied to the vehicles of a train by fluid under pressure admitted to the brake cylinders on the vehicles. In a brake system embodying the invention the air for moving the piston of the brake cylinder from its normal or "running" (brakes off) position to the end of its stroke in which the brake blocks are in contact with the wheels, is entirely or in part supplied from a sub-auxiliary reservoir. The triple valve 1 is of the ordinary Westinghouse construction except that it is formed with an additional air passage 2 connected by a pipe 3 to a branch 4 of a pressure control valve 5 that is connected by a



branch 6 with a sub-auxiliary reservoir 7. Through another branch 8 and a pipe 9, the pressure control valve 5 is connected to the brake cylinder 10. The additional air passage 2 is controlled by the triple valve slide valve 11, which is formed with a small port 12 which places the additional air passage 2 in free communication with the air supply or auxiliary reservoir 13 when the triple valve is in the "brakes off" or running position. The pressure control valve 5 comprises a casing provided with the three branches 4, 6 and 8, the branch 4 for connection to the additional air passage 2, the branch 8 for connection with the brake cylinder 10, and the branch 6 in communication with the sub-auxiliary air reservoir 7. Between the branch 4 and the branch 6 is a valve 14 which, in the normal "brakes off" position, is maintained open by a spring 15 located above a piston-valve 16 arranged to work in the upper part of the valve casing 5. On one side of the piston-valve 16 the valve casing 5 is in free communication with the atmosphere through an opening 20, and the piston valve 16 is formed with leak ports 21 whereby compressed air coming from the brake cylinder 10 through the branch 8 can slowly escape to the atmosphere. The construction and arrangement are such that normally in the "running" (brakes off) position the valve 14 is open and compressed air from the triple valve casing 1 passes into the sub-auxiliary reservoir 7. Upon an application of the brakes, air from the sub-auxiliary reservoir 7 can pass through a channel in the triple valve slide valve 11 to the brake cylinder in order to move the piston thereof to the end of its stroke for moving the brake blocks into contact with the wheels. When the brake blocks are on, compressed air flows from the brake cylinder and acts on the piston valve 16 and moves it on to a seating formed on the cover 23, which closes communication with the atmosphere through the port 20, whereupon, under the pressure of a spring 24, the valve 14 closes, and any further pressure of air required in the brake cylinder must come from the ordinary supply reservoir 13. Upon normal "brakes off" position again occurring, the parts of the pressure control valve again assume their normal position, the compressed air below the piston 16 having escaped back into the brake cylinder and from there to the atmosphere through the triple valve exhaust port in the ordinary way. (*Accepted December* 28, 1923.)

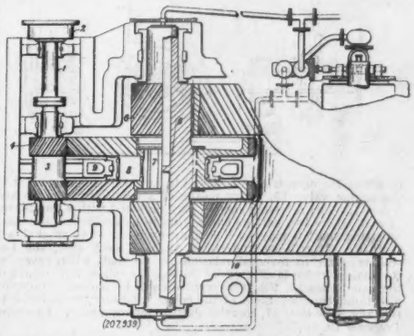
STEAM ENGINES, BOILERS, EVAPORATORS, &c.

206,361. J. S. Atkinson, Westminster, and Stein and Atkinson, Limited, Westminster. Furnaces. (5 *Figs.*) November 7, 1922.—Furnaces for the combustion of fuel, particularly towns' refuse, comprise a slotted, or otherwise perforated, and jacketted fuel-carrier 12, to one end of which are connected a fuel supply 7-9 and a combustion chamber 2 containing elements of a steam generator, an ash receiver 21 being disposed at the other end, and means are provided to supply air to the jacket and therefrom to the fuel. The carrier, which is adapted to be moved to cause the fuel to travel from one end to the other, may be cylindrical and rotatable, and has a perforated lining 24, and the two parts constitute a jacket 25, which is divided by transverse divisions 27 and longitudinal divistons into compartments. The jacketted portion is partially enclosed by a casing 29 divided by divisions 30 disposed symmetrically with respect to the divisions 27, and this casing is continued below the cylinder 12 as a number



of separate funnel-like extensions 31, each corresponding to a division of the casing. Pipes connected to the funnel members 31 are in communication with the outlets of fans or blowers, the inlets of which are connected with an air-heater 5 or with the atmosphere. Air may also be supplied to pipes 35 connected to the ash receiver 21, and thence to pipes 36, which communicate with the funnel members. The upper part of the cylinder 12 is lined with fireclay 26 to form an imperforate hearth, and rings 37-38 are mounted at intervals of the length. Rotation of the cylinder is obtained by means of an electric motor through suitable gearing 14, the cylinder being mounted on rollers 13. In a modification, a duct 20 at the ash receiving end is connected by a damper-controlled flue with the combustion chamber 2, so that the combustion products may be controlled and caused to pass to the combustion chamber 2, either solely through the flue 19 or partly through the flue 19 and partly through the flue in connection with the duct 20. (*Sealed.*)

207,939. R. and W. Hawthorn, Leslie and Company, Limited, Newcastle-on-Tyne, and R. B. Armstrong, Newcastle-on-Tyne. Gear Transmission Devices. (4 *Figs.*) October 10, 1922.—The invention relates to gear transmission devices. The present invention is characterised primarily by



the feature that the primary gear wheel is restrained against axial movement while the primary pinion and the secondary pinion are floatable relatively thereto. There is connected to a driving shaft (not shown) by a flexible coupling 2 and a primary shaft 1 a primary pinion 3 having oppositely-directed helical

teeth 4, the coupling being arranged to permit the pinion 3 to float relatively to the driving shaft; 5 denotes a secondary pinion, which is also provided with oppositely directed helical teeth 6, and which is formed with a splined hub 7, whereon is mounted the correspondingly splined boss of a primary gear wheel 8 which meshes with the pinion 3, the secondary pinion 5 being free to float axially within the splined boss. The teeth of the primary gear wheel 8 are arranged in spaced rows between which is accommodated a journal 9 supporting and centralising the primary gear wheel 8 independently of the secondary pinion 5. The main wheel 10 meshes with the secondary pinion 5. (*Accepted December* 19, 1923.)

208,178. H. E. Partridge, Wolverhampton, V. Smith, Wolverhampton, A. E. Thompson, Wolverhampton, and John Thompson Water Tube Boilers, Limited, Wolverhampton. Apparatus for Removing or Conveying Ashes. (12 *Figs.*) June 17, 1922.—The invention relates to apparatus intended for removing ashes from the furnaces of steam generators. The invention contemplates the use of a liquid for the removal or conveyance of ashes and relates to apparatus which includes the provision of a conduit or chamber containing liquid into which the ashes drop and means for maintaining a flow in the liquid so that the ashes will be carried to a discharging point. The invention employs a series of what are known as "air lifts" for creating and maintaining the flow of the liquid. In carrying out the invention, there is arranged beneath the furnace or furnaces or ash receiving point or points 1 a conduit 4 for liquid constructed to provide a series of horizontal or downwardly-inclined troughs or passages with intervening vertical or upwardly-disposed connecting ducts 5 into the lower parts of which

Fig.1

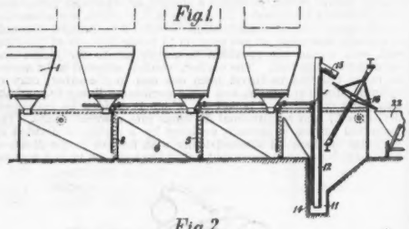
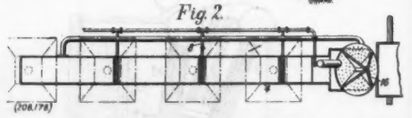


Fig. 2.



air is discharged by a pipe 8 so as to maintain a flow in the liquid whereby the ashes which are discharged therein are carried to a delivery point. The troughs have inclined bases 6 so that the ashes dropping into the liquid at any point along their length will be mechanically deflected towards the end where the air lift apparatus is situated. The air under pressure supplied by the pipes 8 enters directly under passages or conduits 5 and the liquid together with the ashes is thus caused to flow from one end of the trough 4 to the other whence it is discharged into a pit 11. The pit 11 is provided with an upright pipe 12, the lower end of which is open. Adjacent the lower end of the pipe 12 is a branch 14 from the air supply pipe and the liquid and ashes are raised through the pipe 12 and discharged through a pipe 15 on to a disc 16 which is mounted for rotation. The disc 16 is perforated and the liquid escapes through the openings in the disc, whilst the ashes are conveyed to the lower side of the disc from whence they fall into a truck 22. (*Accepted December* 28, 1923.)

208,077. J. G. Barclay, Kilmarnock, A. N. Barclay, Kilmarnock, and Barclay and Co., Limited, Kilmarnock. Reversing Gear. (3 *Figs.*) April 17, 1923.—The invention relates to an improved reversible-throw eccentric for reciprocating engines. The crankshaft 1 is polygonal in section and slidable thereon is a collar 2 having a ring 3 engaged by forks 4 on a reversing shaft 5. The collar 2 carries a pair of cheeks 6, which are slotted at 7 to engage a pair of rollers 8 carried by wings 9 which extend from the eccentric 10. The eccentric is slotted at 11 for sliding movement over the crankshaft 1, and also is slotted to allow the cheeks 6 to slide therethrough. The strap 12 sur-

Fig.1

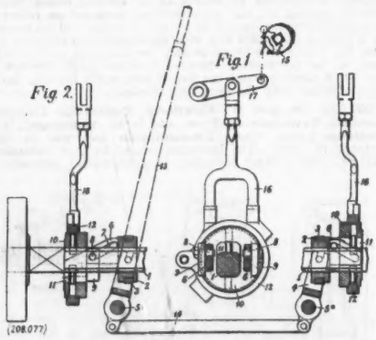
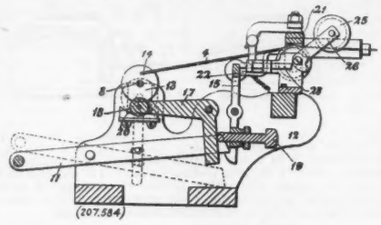


Fig 2.

rounding the eccentric 10 is linked in any convenient manner to the engine valve 15, as by means of a connecting rod 16 and lever 17. The reversing shaft 5 may be fitted with a hand-lever 13 and, where two parallel engines are to be controlled, the main reversing shaft 5 may be linked up by a rod 14 to an auxiliary shaft 5a. It will be understood that, in such case, the two eccentrics are in reversed relationship, so that, when reversing the engine, which is effected by shifting the collars 2 by means of the hand lever 13, the two eccentrics will be moved in opposite directions, the movement of the collar 2 causing the rollers 8 to ride along the slots 11, thereby shifting the eccentrics. (*Accepted December* 19, 1923.)

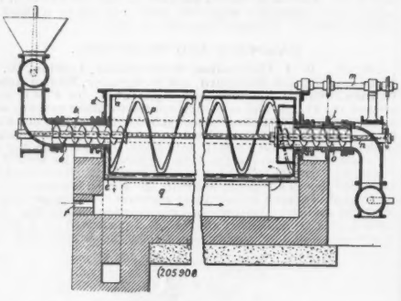
MISCELLANEOUS.

207,584. The Macintosh Cable Company, Limited, Derby, H. E. Sewell, Mickleover, and J. Hines, Derby. Machines for Winding Wire. (3 *Figs.*) August 3, 1922.—The invention relates to the kind of machine for winding wire from large reels to small reels for machine use and commercial purposes, which is arranged so that the mechanism will be automatically stopped when the reel is full, when knots or rough wire appear, when the wire breaks, or when the end of the wire comes up. The invention is characterised by a cranked lever 17, pivotally mounted in the frame and having a roller 18 at one end bearing on the under side of the reel which is being wound, the other end resting against an adjustable set screw 19 in the lower end of a trip gate 15, which determines the amount of winding on the reel; when the reel has reached the desired diameter, the trip gate 15 is pushed away by means of the cranked lever 17, the parallel levers 11 are allowed to fall, and with them the winding-spindle bearings 13 and winding spindle 8. This allows the belt driving the spindle 8 to slacken and slip on the pulley 14, the pulley 14 falling on to a rubber pad or brake block 20 attached to



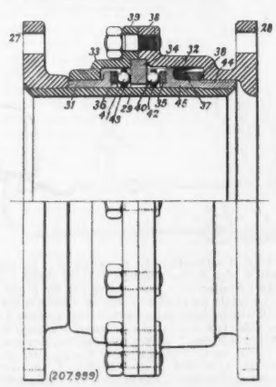
the frame 12 of the machine; thus the machine is automatically stopped. Adjustable dies are fixed to an eccentrically pivotted bracket 21, to which a striker 22 is fixed, the striker bearing against the upper end of the trip gate 15. Should a knot appear in the wire 4 it will wedge in the dies, swinging the bracket 21 about its pivot in a forward direction which, by means of the striker 22, will push forward the trip gate 15, releasing the parallel levers 11 and stopping the machine. A pulley 25 riding on the taut wire is attached to the end of an arm 26, which is pivotted to a bracket attached to a traverse bar, the arm having a cam formed at its other end working in conjunction with a striker 28, which bears against the top of the trip gate. Should a break occur in the wire 4 the pulley 25 falls, pushing forward the trip gate 15 by means of the striker 28 and stopping the machine. (*Accepted December* 12, 1923.)

205,906. Woodall, Duckham and Jones (1920), Limited, London, and Sir A. McD. Duckham, London. Heating Apparatus. (2 *Figs.*) July 28, 1922.—In heating apparatus of the kind in which the materials, *e.g.*, those employed in the manufacture of chemical products such as permanganates, are caused to travel through a heated rotating cylinder, the cylinder *a* is wholly or partly immersed in molten lead or other metal *c* contained in a stationary bath *d*. The cylinder is supported at its ends by means of hollow trunnions *b*, which are rotated from a shaft *m* by chain or like gearing *l*, and contain spiral conveyors *o* for feeding the



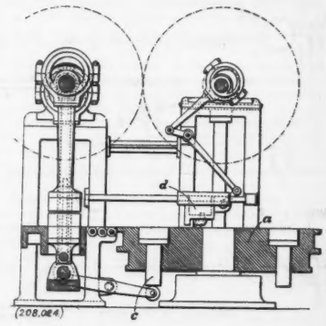
material into and delivering it from the cylinder, the conveyors *o* being mounted on a shaft *n* also operated from the shaft *m*. In the interior of the cylinder a helical blade *p* is fixed for causing the material to travel through the cylinder in contact with the inner surface thereof. The extent of immersion of the cylinder may be varied according to the weight of the contents, so as to minimise the friction on the bearings. In the arrangement shown, the bath *d* is mounted in the flues *q* of a furnace, the products of combustion entering at *r* and being discharged by the outlet flue *s*. (*Sealed.*)

207,999. W. H. Dorman and Co., Limited, Stafford, and O. H. G. Steed, Stafford. Rotatable Pipe Joints. (1 *Fig.*) November 27, 1922.—The invention relates to rotatable pipe



joints of the spigot and socket type provided in the socket with a thrust ball bearing and a U-shaped or other packing on the fluid pressure side of the ball. 29 is the spigot member and 32 the socket member of the joint, and which are provided with connecting flanges 27 and 28. The spigot 29 has secured on its end a flanged retaining sleeve 30, a loose sleeve 31 is also provided on the spigot. The socket member of the joint consists of two annular members 32 and 33 having flanges 38 and 39 whereby they are detachably bolted together. The flanges 38 and 39 are arranged to hold between them a central flange or thrust ring 34 on the opposite faces of which are arranged sets of ball bearings 40 and 41 supported in cages 42 and 43. The opposite sides of these sets of balls bear against ball races 35 and 36 secured respectively in the sleeves 30 and 31. The end of the sleeve 31 fits in a reduced bore provided in the outer end of the socket member 33 and its end abuts against the boss of the flange 27, while the end of the sleeve 30 fits in a reduced bore provided in the socket member 32. Between the sleeve 30 and the bore of the socket member 32 is fitted a U-shaped packing ring 37 held against the flange of the sleeve 30 by means of a ring 38, suitable grooves or openings 44 being provided in the sleeve 30 and ring 38 whereby fluid can pass from the system into the U-shaped packing ring 37. (*Accepted December* 19, 1923.)

208,024. T. Stanley, Cobridge, Stoke-on-Trent, and T. S. Whitfield, Basford, Stoke-on-Trent. Brick-Making Presses. (9 *Figs.*) January 3, 1923.—The invention relates to brick-making presses. According to the invention, the pusher *d*, by which the blocks of moulded material are transferred from the revolving mould table *a*, is formed as, or provided with, an oil receptacle adapted for the feed of oil to wicks or blocks of absorbent material carried thereon in such manner that in the forward movement of the pusher for the transfer of the blocks of moulded material, the wicks are traversed across the face of the



plungers *c* by which the blocks are ejected from the mould table, so that the faces of the plungers are lubricated, while upon the return movement of the pusher the wicks are carried across the face of the blocks of moulded material which are contained in the succeeding moulds or recesses of the revolving mould table. According to the invention, moreover, the pusher *d* is advantageously formed as the oil receptacle, and is provided at the lower end with a holder or holders for the wicks, which are advantageously disposed in an inclined position. (*Accepted December* 19, 1923.)

207,630. Bowden Wire, Limited, Willesden Junction, and A. H. Nisbet, Willesden Junction. Bowden Wire Mechanism. (3 *Figs.*) September 1, 1922.—The invention relates to Bowden wire mechanism and provides improved and simple apparatus whereby a movable device can be actuated and controlled through Bowden wire mechanism from two or more different points, the actuation from said points being independent of one another and obtained at the discretion of the operator. The invention refers to apparatus of the kind in which it has been proposed to control the movable device through a single length of Bowden wire or like mechanism, the inner wire of the mechanism being continuous and the device actuated by a direct pull on the inner wire, such as by means of a hand-lever, and the outer member of the mechanism being divided and the movable device being adapted to be actuated also by means of a foot lever or the like acting upon one of the divided portions of the outer member. According to the invention, one, *b*, of the divided portions of the outer member of the Bowden wire mechanism is arranged to butt against a pivoted block *h* and the other divided portion, *a*, of the member butts directly against the foot lever *e* or the like, and means are preferably provided whereby the foot lever *e* can be adjusted to adapt the apparatus to the angularity, rela-

Fig.1.

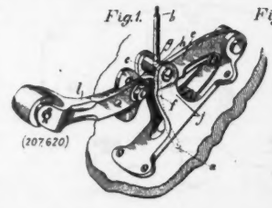


Fig. 2.

tively to the horizontal, of the particular support to which the apparatus is fixed. In carrying out the invention, for instance, in connection with means for controlling the throttle of an internal combustion engine by hand and by foot, one end *a* of a single length of Bowden wire mechanism is connected to the throttle, whilst the other end *b* of the mechanism is connected to any suitable form of hand lever. The inner member *c* of the Bowden wire mechanism passes through an aperture *d* formed in a foot lever *e*, and the outer member of the mechanism is divided intermediate the ends of the latter, and one of the divided ends *f* of the outer member butts against the foot lever, whilst the other divided end *g* of the outer member butts against a swivel block *h* pivoted on a bifurcated bracket *j* to which one end of the foot lever is also hinged or pivoted. The other and free end of the foot lever is extended by a separate pedal proper *l*. With this construction, when the hand-control device is actuated the throttle is moved by the direct pull on the inner wire *c* of the Bowden wire mechanism by the hand control device, and when the foot lever *l*, *e* is operated, the foot lever actuates the throttle by directly compressing the section of the outer member butting against the foot lever; thus the hand and foot-control devices act on the single length of the mechanism. (*Sealed.*)